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Professional learning communities on phenomenon-based science pedagogy: Contrastive cases of urban elementary teachers

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Professional learning communities on phenomenon-based science pedagogy: Contrastive cases of urban elementary teachers

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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this thesis. The Graduate College will ensure this thesis is globally accessible and will not permit alterations after a degree is conferred.

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DEDICATION

To my past and future students for inspiring, teaching, and motivating me to educate. And to all those who devoted their time and efforts in supporting my goals, ambitions, and education journey, I thank you for your love, guidance, and encouragement that has made this all possible. I am forever grateful for you – my mentors, peers, family, and friends. Also, I cannot but help myself in dedicating part of this to my animals, for they have sacrificed some extra attention during this process.

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GLOSSARY OF IMPORTANT TERMS

Term	Abbreviation	Description (For purposes of this study)
Ambitious Science Teaching	AST	A phenomenon-based science teaching framework that uses the four core teaching practices: (1) planning for engagement with important science ideas, (2) eliciting students' ideas, (3) supporting ongoing changes in thinking, and (4) pressing for evidence-based explanations (Windschitl, Thompson, & Braaten, 2018).
English Language Learners	ELL	Students who's native language is one other than English and they are in the process of developing their English language proficiency (What is an ESL Teacher?, 2020).
English as a Second Language	ESL	ESL teachers work with ELL students to improve their English fluency (What is an ESL Teacher?, 2020).
Full Option Science System	FOSS	A K-8 science curriculum that incorporates the Next Generation Science Standards. Used by both participating schools (Full Option Science System, 2020).
Next Generation Science Standards	NGSS	Multi-state-developed K-12 science standards adopted by the participating schools (Next Generation Science Standards, 2019).
Public Health Project	PHP	The NIH-funded project that supported this study and the PHP-PLC.
Professional Learning Community	PLC	A professional development method that respects teachers' knowledge and focuses on improving teacher practice with the main goal of benefiting students' learning outcomes (Vescio, Ross, & Adams, 2008).
Socioeconomic Status	SES	Social class and subjective social status the includes, but is not limited to, income, educational attainment, financial security, etc. (Education and Socioeconomic Status, 2020).
Self-Efficacy	SE	Personal science teaching efficacy (PSTE) and science teaching outcome expectance (STOE)
Anara Elementary School	School A	Participating Midwestern, urban elementary school with two PHP-PLC teams: Team A4 and Team A5.
Baya Elementary School	School B	Participating Midwestern, urban elementary school with two PHP-PLC teams: Team B4 and Team B5.

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ABSTRACT

A majority of educators are ill-prepared to teach culturally relevant and reform-based science, especially in socioeconomically-stressed, diverse urban settings. Inadequate teacher quality has contributed to an annual inequality for historically-excluded students that has accumulated to create a long-term disparity. The purpose of this qualitative, comparative case study was to address these inequities by creating a science professional development intervention for elementary educators teaching at two socioeconomically-stressed, highly diverse urban schools. My aim was to positively influence their science teaching identities in order to improve students' learning experiences. Seventeen teachers participated in the year-long professional learning community and focused on a phenomenon-based science teaching approach: Ambitious Science Teaching (AST). I interviewed, surveyed, and observed the teachers in order to see the impacts of the intervention. My research questions were (1) How does a Professional Learning Community focused on a phenomenon-based science teaching framework affect elementary educators' science teaching identities –self-efficacies, beliefs, and practices? And (2) How do these influences relate to and reflect particular school contexts and teacher characteristics? I found that the elementary educators' contexts influenced their experiences with the intervention and overall, their science teaching identities improved throughout their participation. The AST framework opened their eyes to the essential importance of student-centered science and deepened their concern about the district-adopted curriculum, FOSS, which they understood -- contrary to its intent and claim -- to be a constraint on their teaching.

CHAPTER 1. INTRODUCTION TO THE THESIS

Danielle, an enthusiastic second-year educator, proudly shared her experience around science teaching with me at the beginning of the school year. She exclaimed, "If I had the choice to teach science all day long, I would...I think that having all these STEM background classes have really helped me be prepared to teach science in the classroom" (Danielle, Pre-interview, September, 27th, 2018). We continued our conversation by discussing her current science teaching practices, the challenges she faces, and her goals for the future. Many of the practices she mentioned were aligned with student-centered methods, but she mentioned how letting go of control can be difficult for her. She was eager to participate in the science education Professional Learning Community in order support her journey in improving her release of responsibility. As a new staff member of the fifth-grade teaching team at Baya Elementary School, Danielle was entering with a high science teaching self-efficacy and positive outlook on the year to come.

Background and Significance

I met Danielle in my work as the Graduate Research Assistant (GRA) for the National Institutes of Health (NIH)-funded Public Health Project (PHP) at Midwestern University. She was one of seventeen teachers from two urban elementary schools that I had the pleasure of collaborating with during my implementation of the Public Health Project-Professional Learning Community (PHP-PLC) – a year-long professional development intervention focused on creating a science unit using the phenomenon-based framework, Ambitious Science Teaching (AST). AST utilizes evidence-based practices and was constructed by a team of professionals based out of University of Washington (Windschitl, Thompson, & Braaten, 2018). The PHP team had been adopting AST practices to support these two urban elementary schools' students and communities with many informal science education programs, and they aimed to expand their involvement by engaging in the formal school settings. One of my tasks as the GRA was to enact this expansion by recruiting interested teachers, developing a professional development plan, and facilitating meetings. During this process, I took an interest in learning about science teacher identity and how a PLC might affect it, which was influenced by my past experiences as a pre-service teacher and my own emergent teacher identity development.

Prior to my GRA position, I was an undergraduate student in the elementary teacher preparation program at Midwestern University. The preparation program provided me with many opportunities to observe in-service teachers, including a couple of whom later participated in the PHP-PLC. I began to notice that what I was learning in my coursework was not always aligned with real-life practice. Specifically, I was intrigued by science education and notably the lack thereof within school classrooms. My professors lectured on research-based science pedagogical methods and expressed the importance of science, but I rarely witnessed in-service teachers utilizing these approaches. Some teachers even blatantly told me that what was taught at the university would oftentimes not translate to reality. From all this, I began to develop a deep curiosity about the disconnect between research and practice. My inquisitiveness only became stronger after starting graduate school and diving into the research literature focused on science education reform. I learned that a prominent science teaching approach often supported by researchers is inquiry-based pedagogy which uses questions and hands-on activities as the driving force of student learning (Geier, et al., 2008; King, Shumow & Lietz, 2001; Wilson, Taylor, Kowalski, & Carlson, 2010).

The teachers who participated in the PHP-PLC are part of a public-school district that says it employs an inquiry-based science curriculum. However, based on both my experiences with the teachers and state-reported science standardized test scores, I did not see the intended impacts of inquiry-based science working. I inferred that this gap between what the literature was deeming effective and what I was observing at the schools had a complicated explanation involving an interconnected web of influential factors, not just the pedagogical approach itself. I concluded that if I could create, implement, and document the impacts of a professional development intervention focused on a science pedagogy that incorporates inquiry-based practices, then I would be able to gain a deeper understanding of this gap. What I found striking about Danielle's and the other participants' experiences was that their shared scenarios and obstacles did not determine shared outcomes. Therefore, in my master's thesis, I narrowed my focus to one part of this complex science education web, only to find a smaller entanglement of intricacy: teacher identity. For the purposes of this study, I specifically look at science teacher identity by investigating three connected elements – self-efficacy, beliefs, and practices – in order to simplify and organize my analytical process, while understanding that identity is not solely influenced by these categories. I conducted a qualitative, comparative case study to attempt disentangling how the professional development intervention impacted the educators' science teaching identities.

The Problem

On the critical topic of identity, there is a perpetuated, intentional, and unjust overrepresentation of white people in science professions. The science field has historically reinforced and justified discrimination among multiple marginalized identities and, still today, science is not seen as a "field for all" (Landivar, 2013; Tucker, 1994). Based on recent K-12 standardized test statistics, this pervasive inequity begins long before reaching the professional science career realm. According to the 2015 National Assessment of Educational Progress (NAEP) science assessment report, K-12 students of color score significantly lower than their white counterparts even when socioeconomic status is taken into consideration and compared (Elementary and Secondary Mathematics and Science Education, 2015). This imbalance is frequently referred to as an "achievement gap," but as Gloria Ladson-Billings (2006) argued, it is an annual inequality that has accumulated to create a long-term disparity which she termed "education debt." Many elements add to and affect this debt build-up, including how a majority of educators are ill-prepared to teach culturally relevant and reform-based science, especially in socioeconomically-stressed, diverse urban settings (AEE, 2005; Mayer, Mullens, & Moore, 2000; Moore, 2008b; Santau, Secada, Maerten-Rivera, Cone, & Lee, 2010).

Inadequate educator preparation for socioeconomically-stressed, highly diverse urban schools starts during pre-service teacher programs (Aragon, Culpepper, Mckee, & Perkins, 2014; Moore, 2008b) and is maintained throughout in-service teacher careers as they are more likely to be provided low-quality professional development opportunities than teachers at wealthy suburban schools (Green & Allen, 2015). High-quality professional development interventions focused on reform-based science pedagogies, many of which use inquiry-based approaches, have resulted in positive outcomes related to student assessment scores in science (Lakshmanan, Heath, Perlmutter, & Elder, 2011; Lee, Hart, Cuevas, & Enders, 2004; Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013). Other than analyzing student achievement scores, a more recent method researchers have incorporated in measuring the effectiveness of educator professional development interventions is investigating teacher identity (Avraamidou, 2014). A popularly researched component of teacher identity is their self-efficacy: how an individual perceives their own capabilities (Bandura, 1977; 1989). Studies have shown that educators with lower self-efficacy are more likely to adopt ineffective, teacher-oriented beliefs and practices, which negatively impacts student achievement (Dembo & Gibson, 1985; King, Shumow & Lietz, 2001).

Purpose and Objectives

The purpose of this qualitative, comparative case study was to address these inequities by creating a science professional development intervention for elementary educators teaching at two socioeconomically-stressed, highly diverse urban schools. My goal was to offer insight on how the intervention impacted the educators' science teaching identities – their self-efficacy, beliefs, and practices – by systematically analyzing two participants' experiences as embedded within the overarching findings and situating it all in their broader contexts. I chose to study teacher identity as it relates to science education because the research literature has continuously revealed that there is a strong connection between teacher identity and student achievement (Settlage, Southerland, Smith, & Ceglie, 2009; Tschannen-Moran, Hoy, & Hoy, 1998). I anticipated that exploring the effects of the PHP-PLC on science teacher identity would contribute to the overarching goal of pinpointing effective school-reform solutions, especially for those in similar situations as Danielle and the other participants.

Another objective I had while conducting this study was to gain insight on how the teachers reacted to the phenomenon-based science pedagogy: Ambitious Science Teaching. While the framework incorporates inquiry-based practices, it also includes other research-based teaching methods (Windschitl, Thompson, & Braaten, 2018). However, I was unable to find extensive research in the literature around the use of AST. My personal experiences applying AST practices had demonstrated that it was an effective approach, so I was curious about how in-service teachers in formal education settings would perceive the framework. Therefore, I included questions in my data collection instruments to examine participants' reactions on AST.

I believe that new teaching approaches are important to explore, especially when academic inequities continue to exist between students of marginalized identities and their counterparts.

Research Questions

After determining the existing problems, defining my purpose, and deciding my goals, I created the following research questions in order to organize my investigation on the impacts of this professional development intervention:

1. How does a Professional Learning Community focused on a phenomenon-based science teaching framework affect elementary educators' science teaching identities?
   a. How does it affect their self-efficacy?
   b. How does it affect their beliefs?
   c. How does it affect their practices?
2. How do these influences relate to and reflect particular school contexts and teacher characteristics?

I turned to the research literature for guidance on how to best implement a high-quality Professional Learning Community (PLC), and I describe what I learned in Chapter 2. I explore prior research by attending to three major themes in the scholarly literature: science education, science teacher identity, and teacher professional development, as demonstrated in *Figure 1.1*.

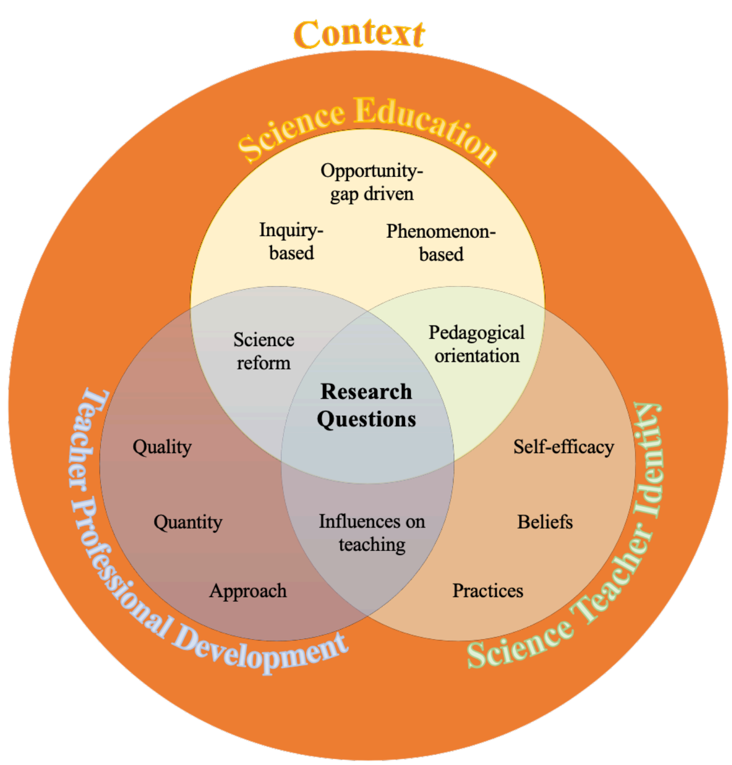

Figure 1.1 Three themes of my research.

These three themes tie my research questions together. In the next chapter, I will review the scholarly literature related to these themes and demonstrate their interconnectedness. My discussion of all these themes pays attention to contextual factors to attend to my second research question.

CHAPTER 2. REVIEW OF THE LITERATURE

In order to familiarize myself with Danielle's classroom context, I sat in on a short lesson near the beginning of the school year. She had the students' desks arranged into five groups of six, with each spot filled. I learned from Kourtney, the most experienced teacher in this PHP-PLC team, that Baya Elementary School's administration had not been fulfilled their promises to add a fourth 5th-grade teacher for the past few years (Kourtney, Pre-Interview, September 27th, 2018). Unfortunately, this left Danielle – a novice teacher new to the school – with the demanding responsibility to educate and accommodate thirty students. I could not help but wonder how the large class size was impacting Danielle's science teaching methods. When I asked her to explain a typical science lesson structure, she explained that, "Right now, it's just kind of boring because...there's not really a whole lot of experimentation that's going on with it. A lot of the time, they're just...at their seats working" (Danielle, Pre-interview, September 27th, 2018). Although Danielle appeared to have strong teaching self-efficacy and a sufficient understanding of effective science pedagogical methods, I began to feel concerned about obstacles she may face with enacting student-centered practices.

Teachers and students in socioeconomically-stressed urban schools, like Danielle and her pupils, face many challenges their suburban counterparts are less likely to endure, such as a lack of resources, low teacher-retention, high student-mobility, lack of support for English Language Learners, etc. (AEE, 2005; Geier, et al., 2008; Jones, Gardner, Robertson, & Robert, 2013). According to the National Center for Education Statistics' Schools and Staffing Survey (2012), the average amount of students in self-contained elementary classrooms is around 21. Danielle's class size was significantly larger than average, only increasing the importance of her classroom management and teaching skills. The ability of Danielle and teachers like her is critically significant because a majority of students in their classrooms come from marginalized populations, which have historically been underserved by the education system and perform less successfully on standardized tests (Logan & Burdick-Will, 2017). The stark annual score differences are commonly labeled as the "achievement gap," but it is clear that marginalized students are not provided equitable learning opportunities. Gloria Ladson-Billings (2006) shifted the narrative from focusing on students' scores to understanding that these perpetuated disparities accumulate to create an "education debt." Continuous lack of access to high-quality education establishes an opportunity-gap that leads to the achievement-gap.

One specific inequity contributing to the education debt is the imbalanced rate of low-achieving urban schools employing a higher quantity of lower-qualified teachers (AEE, 2005; Mayer, Mullens, & Moore, 2000; Moore, 2008b; Santau, Secada, Maerten-Rivera, Cone, & Lee, 2010). Educator quality is often maintained throughout their careers at low-achieving urban schools as they are provided lower-quality professional development opportunities than their counterparts (Green & Allen, 2015). Study after study has demonstrated how teacher quality is connected to student achievement and attitudes towards science (Akerson, 2005; Geier, et al., 2008; King, Shumow & Lietz, 2001). In general, marginalized students in urban schools score lower on standardized tests in all content areas, including science (Logan & Burdick-Will, 2017). According to the 2007 Trends in International Mathematics and Science Study (TIMSS) report, U.S. students of Black and Hispanic backgrounds scored significantly lower than white students, which shows that the science opportunity gap continues to be a widespread problem (Santau, Maerten-Rivera, Jaime, & Huggins, 2011). Therefore, an approach to combatting these inequitable learning opportunities is to implement high-quality professional development interventions in highly diverse, socioeconomically-stressed schools that are focused on reform-based science pedagogies. Many previous interventions utilize inquiry-based science teaching methods and have been successful in improving students' achievement scores (Lakshmanan, et al., 2011; Lee, et al., 2004; Mintzes, et al., 2013).

Specific to this study, the participants teach at two urban public schools in the Midwest and have been using an inquiry-based science curriculum for over a decade, yet an opportunity gap still prevails between students of marginalized groups and their counterparts. According to the government website that releases standardized-test score data for these two schools, around 8% of the fifth-grade students are meeting the proficiency achievement benchmark in science compared to the 57% state average (Note: a citation is not provided in order to protect the anonymity of the schools). Knowing that the schools use a research-based science curriculum and learning from pre-interviews, like from Danielle's, that the educators proclaim an understanding of effective teaching strategies, I engaged with the preexisting literature to gain more insight on why the opportunity-gap prevails. Although Danielle started off the year with high self-efficacy and a good knowledge base on student-centered practices, I wondered how this would translate to effective teaching? Moreover, I wanted to understand how, in my role with the PHP, how I could best support the participants' science teaching identity – as understood through their science teaching self-efficacy, beliefs, and practices – to ultimately positively impact their students' achievement?

Orientation to Knowledge and Knowledge-Making

In order to respond to these interests, I drew on three fields within the research literature: science education, science teacher identity, and teacher professional development. I took notice of the intersecting elements between these fields and the context that engulfs them. I orient my understanding of knowledge and knowledge-making through a constructivist-interpretivist lens, which I explain in Chapter 3. Essentially, I view reality as something that does not exist outside of people's social construction and interpretation of the world (Rossman & Rallis, 2017). I also strive to look at things through a critical lens in order to see past the dominant narrative. To aid in answering my research questions, I explore one major theoretical framework: Social Cognitive Theory. My research questions are:

(1) How does a Professional Learning Community focused on a phenomenon-based science teaching framework affect elementary educators' science teaching identities: self-efficacy, beliefs, and practices?

(2) How do these influences relate to and reflect particular school contexts and teacher characteristics?

Social Cognitive Theory

An essential component connected to teacher quality is self-efficacy, which was originally extensively elaborated on by Albert Bandura within his theory, Social Cognitive Theory (Bandura, 1977, 1989). Unlike behavioral theorists, the Social Cognitive Theory accounts for the social environment and how it affects learning. Bandura explains that people are not totally autonomous nor totally controlled by external, environmental factors (Bandura, 1989). Wood and Bandura (1989) describe this using the triadic reciprocal causation model with its three major factors: behavior, personal, and the environment. Within the "personal" factor of the model are sub-elements, including a person's values, goals, self-efficacy, etc. Self-efficacy was first discussed by Bandura (1977) where he split it into two dimensions: outcome expectancy and personal efficacy. Outcome expectancy involves a person's beliefs about how certain "behaviors" influence certain outcomes. Personal efficacy includes a person's beliefs surrounding their own abilities and effectiveness to administer certain "behaviors." Bandura contrasts these dimensions in his statement, "Outcome and efficacy expectations are differentiated, because individuals can believe that a particular course of action will produce certain outcomes, but if they entertain serious doubts about whether they can perform the necessary activities such information does not influence their behavior" (Bandura, 1977, p. 193).

Bandura later interprets four major elements that affect efficacy expectations: mastery experiences (the most influential), physiological and emotional states, vicarious experiences (where behaviors are modeled by someone else), and social persuasion. If someone often faces "impediments, failures, adversities, setbacks, frustrations, and inequities," they are likely to have a weak self-efficacy (Bandura, 1989). Bandura (1989) suggests that the strength of one's self-efficacy plays an important role in their motivation and ability to perform. A person with a strong self-efficacy is more likely to be persistent, positive-minded, and less apprehensive during specific situations. Cantrell, Young, and Moore (2003) narrowed in on elementary educators and explained that teachers with a strong personal efficacy are more likely than those with a weak personal efficacy to put forth more effort toward a goal and bounce back from any failures.

Science Education

Teachers with low self-efficacy are more likely to adopt ineffective, teacher-oriented beliefs and practices, which negatively impact student achievement and weaken reform-based efforts (Dembo & Gibson, 1985; King, Shumow & Lietz, 2001). As mentioned above, an education opportunity gap in all subject areas exists that negatively impacts historically-excluded youth, especially in socioeconomically-stressed, urban schools (Logan & Burdick-Will, 2017). The gap persists past elementary school and secondary school into the Science, Technology, Engineering, and Mathematics professions' demographics with the overrepresentation of white and Asian men and the underrepresentation of Black and Hispanic women and men (Elementary and Secondary Mathematics and Science Education, 2015; Landivar, 2013). This is significant because STEM professions are often seen as esteemed and are high-paying (Broyles & Fenner, 2010). Tate (2001) makes a case that urban school students' opportunity to learn science is a civil right. He states, “Despite progress in our understanding of how students learn science, the transfer of this knowledge to urban school systems has been painstakingly slow” (Tate, 2001, p. 1018).

Opportunity-Gap Driven

According to the 2015 National Assessment of Educational Progress (NAEP) science assessment report, students who are eligible for free or reduced lunch prices – students of low-socioeconomic status (low SES) – score significantly lower than their counterparts. The average science assessment score for fourth-grade students on the NAEP in 2015 was 154 out of 300 points. During 2015, students with a low SES scored 29 points lower than those with a high SES. The results when comparing students of different races and of socioeconomic status are the following [low SES/high SES]: White [154/172], Black [129/148], Hispanic [134/157], Asian or Pacific Islander [150/178], American Indian or Alaskan Native [134/158], and more than one race [147/171] (Elementary and Secondary Mathematics and Science Education, 2015). These scores demonstrate severe disparities in science education. Students of color score significantly lower than their white counterparts even when socioeconomic status is taken into consideration. White students with low SES score higher than Black students with high SES.

These trends continue through eighth grade and at the end of twelfth grade (Elementary and Secondary Mathematics and Science Education, 2015), and they do not disappear after high school. The gap in these science achievement scores is significant because they carry over into STEM professions. People of marginalized groups, especially Black and Hispanic populations, are underrepresented in STEM careers. Landivar (2013) examined the 2011 U.S. Census Bureau statistics and found that white people make up 67% of the total workforce, yet they held 71% of STEM jobs. Black people made up 11% of the workforce; however, they held 6% of STEM jobs. Similar statistics also rang true for Hispanic people because they made up 15% of the workforce and only held 7% of STEM jobs. Broyles and Fenner (2010) concluded that wage discrimination also exists between employees of different races in STEM careers. They found that in 2005 Black chemists were paid significantly less than white chemists, even though they had similar levels of education and experience. This goes to show that the science opportunity gap does not only exist within education, but it continues into and is perpetuated by the professional field.

Test scores and statistics related to the science opportunity gap call many things into question, including the processes affecting these outcomes. Specifically, how is science being taught, and is it equitable across all schools? Looking at the most fundamental component of science education, how much time is spent teaching science? Blank (2013) answers this in his analysis of the late 2000s National Center for Education Statistics' (NCES) reports presented by the U.S. Department of Education. He found that the average amount of time spent teaching science declined from 2000 to 2008. He also compared the NAEP achievement scores to the amount of instructional time and determined that classrooms with an average of four hours of science instruction per week received significantly higher scores than those with the lowest amount of instructional time, which was around one hour per week (Blank, 2013). I learned from the teachers in my study during our pre-interviews that they had around two hours of science instructional time per week; some even reported it to be less frequent. As for how science is being taught and if it is equitable, Hayes and Trexler (2016) aimed to answer this and conducted a study where they surveyed 182 teachers. They concluded, "Poor and underrepresented students had considerably less chance of being exposed to excellent and engaging science pedagogies than wealthier White and Asian students" (Hayes & Trexler, 2016, p. 285). Their measurement in determining this included asking teachers how often they implemented hands-on and inquiry-based pedagogies. The Midwestern urban schools in this study have been using an inquiry-based science curriculum for over a decade.

Inquiry-Based Pedagogy

Lee, Hart, Cuevas, & Enders (2004) describe inquiry-based science pedagogy as hands-on science instruction that engages students in exploring and generating questions about natural phenomena while also incorporating collaborative group work. In general, inquiry-based science teaching has been found to be successful in some studies and is popular among reform-education practices (Capps & Crawford, 2013; Geier, et al., 2008). One example is a research study that was conducted around the effects of a professional development intervention focused on educating teachers on inquiry-based science pedagogy methods in urban schools. Students of color and ELL students in the study scored significantly lower on the TIMSS pre-assessment than the "norm group." After the professional development intervention where teachers learned about and implemented inquiry-based science teaching strategies, the students of color and ELL students scored significantly higher than the "norm group" (Santau, et al., 2011).

There are many frameworks that utilize inquiry-based practices, a particularly popular one being the 5E learning model (Bybee, 1990), which some of the participants of this study were familiar with. During the elementary educator preparation program that I attended at Midwestern University, our science teaching methodology course was entirely dedicated to learning the 5E model as it has been found to be effective in many research studies (Cakir, 2017). The "5E" stands for the five phases that all begin with "e" in the instructional model: engagement, exploration, explanation, elaboration, and evaluation. This model is based on constructivist views, and while "using this approach, students redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment" (Bybee, 1990, p. 96). Other inquiry-based frameworks utilize similar practices, including the curriculum adopted by the schools in this study.

Currently, the two urban schools utilize a kit-based science curriculum – Full Option Science System (FOSS) – which claims to apply an active-learning, inquiry-based approach that provides meaningful experiences to both students and teachers. The FOSS website states, "FOSS is the result of academic research on learning interwoven with practical experiences in classrooms. FOSS helps all educators teach and manage inquiry-based science. The carefully designed instructional sequences and thoroughly tested equipment provide support for teachers with different experience levels in science." The most recent FOSS curriculum edition – developed within the past couple years – is being marketed on the website with statements such as, "[FOSS is] America's most awarded, most adopted science program," and, "No one has brought active science learning to more classrooms than FOSS" (Full Option Science System, 2020).

In efforts to better understand these claims, I searched for research-based evidence. The official FOSS website has a research database that allows users to search literature related to its curriculum and other categories, including "inquiry-based instruction," "hands-on science," "professional development," etc. When I selected the "effectiveness study" category in the database, fourteen out of 135 results appeared, all of which were published between 1983 and 2010. The most recent study in the entire database was published in 2012. However, it should be noted that new editions of the FOSS curriculum have been released since 2012 in order to accommodate NGSS. One of the pieces under the "effectiveness study" category was a qualitative dissertation focused on elementary teachers' and students' interactions with an earlier version of FOSS. Clementson (1991) observed, surveyed, and interviewed five teachers to gain insight on how they perceived the FOSS curriculum. He concluded that the educators seemed anxious about teaching science prior to using FOSS, but once they adopted the FOSS curriculum, some of the anxiety dissipated. He noted that teachers found FOSS easy to use, and they felt positive about the curriculum.

Outside of the FOSS research database, I was able to find a more recent study that involved the FOSS curriculum. Around 380 third-grade teachers from four Midwestern school districts participated in a two-day professional development workshop focused around one FOSS unit. The goal of the study was to determine the effectiveness of an enhanced version of the curriculum that incorporated model-based explanations as compared to the original curriculum methods. While FOSS focuses on providing students opportunities to observe and conduct experiments, the researchers altered the unit to include scientific modeling. After comparing the results of student learning outcomes from classrooms that used the original versus the altered curriculum, they found that the latter was more effective in deepening students' understanding of the unit's content (Baumfalk, et al., 2019). This study demonstrates that there is room for improvement in at least one unit of the FOSS curriculum. On that note, although research exists on successful elements of FOSS, not all schools adopting this inquiry-based science curriculum have successful outcomes; more specifically, the Midwestern public schools in this study whose science proficiency scores are not so proficient. These are presented in Chapter 3 - *Table 3.1*.

Phenomenon-Based Pedagogy

Phenomenon-based science teaching adopts many of the core components of inquiry-based science teaching, which is described as students engaging in scientifically oriented questions, using evidence in their explanations, comparing alternative explanations to their own, and communicating their justifications (Wilson, et al., 2010). The phenomenon-based science teaching approach utilized in this study's professional development intervention applies pedagogical strategies similar to the 5E and FOSS, but it focuses on connecting multiple science ideas through a specific, real-life event that occurs in the natural world in order to encourage students to find the relationships between the different science concepts. Along with a specific event, this phenomenon-based science teaching framework uses an essential question throughout the unit that is meant to be both relatable to students and open-ended (Windschitl, Thompson, & Braaten, 2018). The use of a focus question makes this type of pedagogy closely related to inquiry-based teaching, which has been proven to be correlated with positive student achievement outcomes. With the success of past inquiry-based science professional developments, it would seem that a similar professional development intervention focused on phenomenon-based science teaching should also be successful if the elements of this pedagogy are effective.

Ambitious Science Teaching

The particular phenomenon-based science pedagogy utilized in this study is the Ambitious Science Teaching (AST) framework developed by a team of researchers primarily based out of the University of Washington. AST has been built using evidence-based science teaching practices that focus on both rigorous and equitable education. The framework was originally focused on secondary science but has evolved to include more information about elementary settings. In the book, *Ambitious Science Teaching*, by Windschitl, Thompson, and Braaten (2018), the authors explained that research in science education over the past few decades has pointed out many effective science teaching strategies, but there lacks a practical and cohesive model for practitioners to readily use. Thus, the creators of AST have addressed this gap by compiling research findings and testing their vision – with hundreds of science teachers from a wide range of contexts and for more than a decade -- in order to generate a practical, evidence-based science teaching framework. They state, “The goal of AST is to help students of all backgrounds to deeply understand fundamental science ideas, participate in the practices of science, solve authentic problems together, and learn how to continue to learn on their own" (Windschitl, Thompson, & Braaten, 2018, p. 3).

To achieve this goal, there are four core sets of practices in the AST framework cycle: (1) planning for engagement with important science ideas, (2) eliciting students' ideas, (3) supporting on-going changes in thinking, and (4) pressing for evidence-based explanations. Notable teaching methods that support these AST practices include utilizing students' prior knowledge, focusing the learning around a natural and complex puzzling event, and incorporating meaningful experiences to engage learners in sense-making and multiple rounds of revising scientific models. In the last chapter of the book, the authors describe how to organize professional development around AST, and they suggest structuring it using a Professional Learning Community setup. Along with this recommendation, I also followed their advice to aim for creating one or two science units, which was the main task-goal of the PHP-PLC (Windschitl, Thompson, & Braaten, 2018). The overarching goal of the PHP-PLC was to influence the participants' science teaching identities, which I discuss further in the next section.

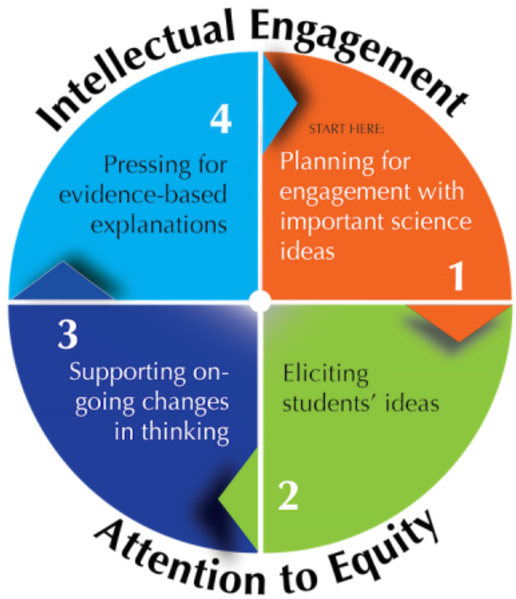

Figure 2.1 Four sets of core practices in Ambitious Science Teaching (Windschitl, Thompson, & Braaten, 2018)

Science Teacher Identity: Self-efficacy, Beliefs, and Practices

Our identity influences how we perceive the world and how the world perceives us. Identity is complex, multidimensional, and unique to every individual. Many theories and frameworks pertain to identity, and some go the lengths of specifying unique identity development processes for particular professions, including teaching (Gee, 2000). A prominent scholar in the teacher identity research field who particularly focuses on science teacher identity is Lucy Avraamidou. In one of her most recent articles, she refers to an argument made by Luehmann (2007) and states, "the construct of identity is particularly important within the field of teacher education because it offers a comprehensive construct for studying teacher learning and development, which goes beyond knowledge and skill" (Avraamidou, 2019, p. 34; Luehmann, 2007). Prior to this, Avraamidou (2014) conducted an extensive literature review over current research in science teacher identity, which included 29 empirical studies. She notes that, prior to the past decade, an understanding of teacher identity in science education research was lacking. One weakness she found to the current literature is that there is not an agreement on how science teacher identity is conceptualized and developed. However, she explains that the consensus for characterizing general teacher identity and teacher identity development – how it is socially constructed, dynamic, complex, etc. – offers insight on understanding science teacher identity and their development, more specifically.

Throughout Avraamidou's (2014) analysis, she pinpoints multiple components that both impact and are closely related to science teacher identity development. These include personal histories and experiences (Day, 2013; Moore, 2008a), self-efficacy, beliefs, and views about science teaching and learning (Eick & Reed, 2002; Saka, Southerland, Kittleson & Hutner, 2013), teaching practices and teaching dilemmas (Upadhyay, 2009), and the context of teaching, such as school culture (Flores & Day, 2006). For the purposes of this study, I focused on three elements interconnected with science teacher identity development – self-efficacy, beliefs, and practices – as they relate to teachers' contexts in order to help me understand how the PHP-PLC intervention affected participating educators. I learned from the literature that it is essential to look beyond knowledge and practices as part of identity (Luehmann, 2007), so I included educator self-efficacy and beliefs around science teaching in my study.

I also aimed to keep the teachers' situations in mind by exploring how context influenced their experiences because many scholars have found context to be impactful on identity construction, self-efficacy, beliefs, and practices (Gee, 2000; Lave & Wenger, 1991). For example, a survey sent in 2001 to measure the self-efficacy of 452 Midwestern, urban schoolteachers found that those with a higher teaching efficacy were working in schools that had a higher collective efficacy (Goddard & Goddard, 2001). This demonstrates the importance of taking context into consideration. Another study where 44 elementary educators were surveyed about science teaching – half of whom were also interviewed – found that "teachers' beliefs were more influenced by their administration and peer group than they were by federally mandated policy" and that, although teachers reported time and resources as major obstacles, "the opinions of others and school mandates were more closely aligned to their emerging practice" (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012, p. 127). Therefore, while my focus is on participants' science teaching self-efficacy, beliefs, and practices, I also investigate their contexts to gain insight on any changes to their science teaching identities.

Self-Efficacy

Bandura concludes within his Social Cognitive Theory that learners who experience deficient results and have low self-efficacy will quickly call it quits compared to those who have sufficient results and high self-efficacy (Bandura, 1977). A major principle of Social Cognitive Theory is that learners hold a specific belief in their abilities, called self-efficacy, which regulates their motivational levels. As I described at the beginning of this chapter, Bandura divided self-efficacy into two dimensions: outcome expectancy and personal efficacy. A person's outcome expectancy is comprised of what they expect to happen based on specific "behaviors."

Someone’s personal efficacy is their beliefs about their own abilities to enact certain “behaviors” (Bandura, 1977, 1989).

The ideas of both “personal efficacy” and “outcome expectancy” have been quite extensively researched within the education field. More specifically, multiple self-efficacy measurement instruments have been developed for teachers in order to analyze its significance for student achievement. Along with others, the Gibson and Dembo’s (1984) Teacher Efficacy Scale (TES) and Riggs and Enochs (1990) Science Teaching Efficacy Belief Instrument (STEBI) utilize Bandura’s two dimensions of self-efficacy. Dembo and Gibson (1985) transform Bandura’s “personal efficacy” into “personal teaching efficacy,” which they describe as the “belief that he or she [personally] has the skills and abilities to bring about student learning” (Dembo & Gibson, 1985, p. 175). They also add the teaching component to Bandura’s “outcome expectancy” when using the term “teaching efficacy,” which are the general beliefs about how and what a teacher can and cannot influence in regard to student learning outcomes. Riggs and Enochs (1990) narrow these two dimensions even further to specify them within science education: personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE). I have implemented these instruments in my study in order to collect data on and analyze how teachers’ self-efficacy affects student learning.

Settlage, Southerland, Smith, and Ceglie (2009) explain that research consistently shows educators with high teaching self-efficacy are more likely to implement effective pedagogical methods and improve both student attitude and achievement. This goes beyond individual teachers’ efficacies and has been found to be “contagious,” as Tschannen-Moran, Hoy, and Hoy (1998) discussed in their extensive review of the meaning and measures of teacher efficacy. Low efficacy around teaching may be transferred between school staff, which can lead to an overall negative climate that affects students' learning outcomes and teacher retainment. There are many variables that influence teacher self-efficacy, which include, but are not limited to, school culture and climate, sense of community – one study found this to be the most influential factor (Lee, Dedick, & Smith, 1991) – principal behavior, teacher autonomy, content, salaries, recognition, support, and so on (Tschannen-Moran, Hoy, & Hoy, 1998). This demonstrates the complexity of teachers' efficacy and shows why the literature is quite dense around this topic. I focus the following section on teacher self-efficacy as it relates to elementary science teaching beliefs and practices.

Beliefs and Practices

With the complex nature of self-efficacy comes, of course, complex correlations between other internal processes. A question I had was, "Does self-efficacy determine one's beliefs, or do one's beliefs determine their self-efficacy?" When discussing a teacher's beliefs about science education, I am referring to what extent a teacher believes they can influence student learning outcomes, how students learn, what students should learn, what role a teacher plays, the purpose of science education, etc. These beliefs affect which pedagogical methods a teacher implements in their classroom – their teaching practices – which then affect how/what the students learn. To measure these beliefs, Riggs and Enochs (1990) incorporated questions on their STEBI survey to determine a teacher's "science teaching outcome expectancy" (STOE), which asks them about the influential level of any teacher on students' science learning. For example, one of the STEBI statements on which teachers self-assess using a five-point scale between strongly agree to strongly disagree is "Effectiveness in science teaching has little influence on the achievement of students with low motivation" (Riggs & Enochs, 1990). The STEBI survey also aspires to determine an educator's "personal science teaching efficacy" (PSTE), which is a teacher's belief about their own abilities to teach science. An example from the survey is "Even when I try very hard, I don't teach science concepts effectively" (Riggs & Enochs, 1990).

Studies using the STEBI survey have shown that teachers with strong STOE can be expected to adopt more reform-based teaching strategies than those who score a lower STOE on the STEBI survey. Teachers with weak STOE are usually less effective in science teaching because they are more likely to use traditional teaching methods, such as text-heavy lessons rather than hands-on activities. Traditional forms of teaching have been found to be less productive in educating students in science (Lardy, 2011); yet, in my experience as a preservice teacher and PHP professional development deliverer, district-required science curricula lean towards more traditional pedagogies. While STOE is important to understand as it connects to beliefs, PSTE has a more reliable prediction on teacher practices (Lakshmanan, et al., 2011). However, although it may allow researchers to make assumptions about teachers and it seems as if increasing a teacher's self-efficacy would improve their practice and student achievement outcomes, studies have shown this to not always be the case (Settlage, et al., 2009).

A teacher's beliefs do not always align with their actual practices, which is important to account for when analyzing data from the STEBI survey. Individuals may have skewed visions and/or understandings of themselves and self-reflect in an inaccurate way, which is why many researchers conduct observations alongside participant surveys. Santau, Secada, Maerten-Rivera, Cone, and Lee (2010) implemented a study about seventy elementary teachers' knowledge and practices in teaching science to English Language Learners over the course of a year-long professional development intervention. The authors concluded that even though some of the educators indicated the use of reform-oriented practices in their science teaching, only a small portion of them actually used these practices. Keeping this in mind, a look into how PSTE affects student achievement is still an important discussion.

Lardy (2011) reviews multiple studies that look at PSTE and the implications for student learning outcomes. One study the author mentions is about a year-long professional development intervention where they found that teachers with a low PSTE were less likely to change their beliefs in how students learn science, as well as be less likely to choose teaching science. Lardy, drawing on the work of other scholars, states the following about teachers with a high PSTE:

> Other evidence suggests that in-service teachers with higher levels of science teaching self-efficacy (a) claim to ask more open-ended questions (Riggs, Enochs, & Posnanski, 1998); (b) do a better job of connecting science content to students' lives and/or the real world (Haney et al., 2002; Riggs et al, 1998); (c) teach more science per week (Desouza, Boone, & Yilmaz, 2004); (d) report using more hands-on activities (Marshall, Horton, Igo, & Switzer, 2009; Ramey-Gassert, Shoryer, & Staver, 1996); (e) incorporate more inquiry-based activities (Haney et al., 2002; Lakshmanan, et al., 2011; Nolan et al. 2011); (f) present scientific content that is more accurate (Haney et al., 2002); and (g) exhibit more positive attitudes toward science education reform (Czerniak & Lumpe, 1996) (Lardy, 2011, p. 13).

Considering there is a positive correlation between teachers who have a high PSTE and the implementation of more effective science teaching practices, researchers are continuing to analyze the complex relationships in order to gain a better understanding of how to improve teacher professional development.

Teacher Professional Development

In 2005, the National Center for Education Statistics administered a survey where 95% of public school teachers indicated that their professional development interventions were mainly workshops and conferences, which are both considered low-quality professional development methods. The National Standards Development Council (NSDC) created twelve standards of high-quality professional development, some of which include continuous instructional improvement, collaboration, looking at student data, and the use of learning communities (Green & Allen, 2015). Green and Allen (2015) conducted a studied on the quality of professional development opportunities and found that teachers in high-achieving schools reported their professional development aligning with the NSDC standards to a greater degree than teachers in low-achieving schools. This finding remains true according to one of the participants who mentioned that she and her colleagues have had one short workshop on inquiry-based science teaching over the past year (Michelle, Personal Communication, September 27, 2018).

High-Quality Professional Development

The literature suggests that, although there are insufficient professional development opportunities offered to teachers in low-achieving schools (Green & Allen, 2015), high-quality professional development interventions focused on science pedagogy have been successful with teachers in urban schools (Lakshmanan, Heath, Perlmutter, & Elder, 2011; Lee, Hart, Cuevas, & Enders, 2004; Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013). I noticed four major components often correlated with high-quality science professional development interventions: (1) the quality and amount of scaffolding provided to the teacher by an expert in the focused upon area, (2) the amount of time spent on the intervention, (3) teacher content knowledge, and (4) the motivation of the teachers to improve their practices.

(1) Scaffolding

In the education field, scaffolding is when a teacher uses pedagogical methods to support a student's advancement in their learning by accounting for their academic level (Vygotsky, 1978). For example, an educator may scaffold a student during a science lesson by providing the student with specific background knowledge that will allow them to better understand more complex content. Scaffolding can be used for all learners, including teachers. A study conducted in 2016 was focused on the effects of different levels of scaffolding with professional development interventions on both teacher self-efficacy and student achievement in science. The researchers of this study facilitated three professional development programs: (1) a self-study intervention with no additional scaffolding (2) a group with low expert scaffolding and (3) a group with high expert scaffolding. The professional development groups that were highly-scaffolded by an expert had higher success rates for both teacher self-efficacy and student achievement compared to the self-study professional development groups (Kleickmann, Tröbst, Jonen, Vehmeyer, & Möller. 2016).

(2) Time

The amount of time teachers participate in professional development interventions is another key component of the rate of success for improved science teaching instruction. Supovitz and Turner (2000) focused on the quality/outcomes of inquiry-based science teaching professional development interventions and found that teachers who attended less than 40 hours of professional development used more "traditional" practices rather than inquiry-based practices. Teachers did not demonstrate the utilization of inquiry-based practices until having attended 80+ hours of professional development. The researchers of this study also reported that "content preparation and attitudes towards reform" played a significant role in intervention results (Supovitz & Turner, 2000).

(3) Content Knowledge

An educator's understanding of the topic they are teaching to their students is referred to as content knowledge (Akerson, 2005). In a research study with over 270 teachers, three types of professional development models focused on science teaching were implemented to find the most effective intervention strategies. Each model provided teachers with some level of content knowledge for the topic they were teaching. A positive relationship between teacher content knowledge gains and student content knowledge gains was a significant result of the study (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012).

(4) Motivation

A major contributing factor to successful and high-quality professional development outcomes is the motivation level teachers possess during the intervention. According to Kennedy's (2016) review of 28 successful professional development programs, teachers attending mandated interventions are believed to have less motivation to learn than teachers who choose to be a part of an intervention. Professional development interventions that required teachers to participate were significantly less successful than interventions with teachers who volunteered themselves (Kennedy, 2016).

Professional Learning Communities

A popular approach to teacher professional development is the implementation of collaborative, flexible, and intimate professional learning communities (PLCs). The PLC method respects teachers' knowledge and focuses on improving teacher practice with the main goal of benefiting students' learning outcomes (Vescio, Ross, & Adams, 2008). Lakshmanan, Heath, Perlmutter, and Elder (2011) implemented a PLC that aimed to improve classroom science practices by offering teachers hands-on experiences and resources. These PLC groups met once a month with two coaches throughout various school years between 2007-2009 where they focused on research-based pedagogies and science content in order to develop engaging lessons. The researchers found that the PLC increased teachers' PSTE and determined that there was a positive relationship between an increased teacher self-efficacy and the amount a teacher utilized standard-based teaching. Mintzes, Marcum, Messerschmidt-Yates, and Mark (2013) took a different approach to a science-focused PLC intervention. They had teachers complete a modified form of Lesson Study, which is where the teachers design a lesson, observe it, and then revise and implement it. For three years, the teachers met twice per month and also participated in one-week summer workshops. By the end of the intervention, the researchers concluded that teachers with low science teaching self-efficacies demonstrated a significant improvement. The teachers also reported that their involvement with the PLC was beneficial to their students' science learning.

PLCs are not always implemented by outside groups, such as the two examples described above. Many schools often adopt PLC programs as a required protocol. Jones, Gardner, Robertson, and Robert (2013) explored 65 urban elementary educators' perceptions of school-based science PLCs and their beliefs on how these interventions affected their science teaching practices. Teachers reported both pros and cons to the PLCs, but the majority believed the PLCs to be beneficial to their practices. Researchers concluded that "Just as science PLC goals differed across schools, there were also distinct differences in the interactions that took place within the PLC meeting structure" (Jones, et al., 2013). This finding demonstrates that the effectiveness of PLCs depends upon a multitude of factors, including context and teacher identities. It seems that science education and reform efforts are complex topics influenced by many intertwined elements.

In my review of the literature, I explored some of these elements and learned that science teacher identity plays an essential role in science education. A prominent connected part of teacher identity is self-efficacy, how its developed, and how it affects the students' academic achievement outcomes. Educators with a strong self-efficacy are more likely to persevere when confronted with difficult obstacles, put more effort into their career, and have more positive well-being (Bandura, 1977, 1989). These connect to increased student achievement by affecting teacher practices (Dembo & Gibson, 1985; King, Shumow & Lietz, 2001). Educators with high scores on self-efficacy measurement instruments, such as the STEBI survey, are more likely to adopt reform-based pedagogy strategies (Mayer, et al., 2000; Moore, 2008b; Santau, et al., 2010). Teachers who are supported, feel a sense of community within the school, and are provided high-quality professional development opportunities are prone to have higher self-efficacy scores that positively impact their enthusiasm and commitment to the career (Mintzes, et al., 2013; Tschannen-Moran, et al., 1998; Vescio, et al., 2008). It is essential that we work towards creating confident, comfortable, and knowledgeable educators, especially in schools where the student population is mostly those with a low-SES (Hayes & Trexler, 2016). Many inequities exist within the education system for marginalized populations (Logan & Burdick-Will, 2017), so understanding the complex relationships between teacher self-efficacy, beliefs and practices is vital to breaking down barriers and closing gaps (Avraamidou, 2014; Gloria Ladson-Billings, 2006). After learning from this literature, I developed an approach to my study, which I describe in Chapter 3.

CHAPTER 3. RESEARCH METHODS

Around the middle of the school year, Danielle's team had a fourth member join our PHP-PLC meetings, which was the newly added 5th grade teacher – making everyone's classroom size go from above thirty to the mid-twenties. Danielle, Kourtney, and Peyton seemed to be quite relieved. After winter break, I wanted to check-in with each participant to see if they had any questions, concerns, or comments about the PHP-PLC since we were about halfway done with our time together. I sent out a Mid-Survey to collect their feedback, and I included a scale for teachers to rate their familiarity with different elements of Ambitious Science Teaching. Danielle responded with a lower-rating of understanding than most other participants, but she did not have any suggestions for changes to the meetings and indicated that it was "all good" (Danielle, Mid-Survey, January 14th, 2019). By this time, we had the first few activities of the science unit outlined in a shared Google Document and were working on organizing around ten more days of lessons. Danielle and her team were planning on implementing the unit near the beginning of April, so we had five more meetings scheduled to complete our goals. Before they taught the unit, I provided another survey – the Pre-Unit Survey – for teachers to list their facilitation goals and concerns. Danielle wrote, "I'm worried I will forget to include the AST aspects and will fall back into my regular ways of teaching" (Danielle, Pre-Unit Survey, April 8th, 2020). I aimed to support Danielle in stepping outside her comfort zone and reaching her goals by thoroughly documenting our plans and providing a variety of resources.

My purpose for this study was to gain insight into how a year-long Professional Learning Community (PLC) focused on the Ambitious Science Teaching (AST) framework affected the science teaching identities of Danielle and the other eleven participating elementary educators. I facilitated the work of four teacher teams who participated in approximately thirty hours of this professional development experience with the primary goal of creating and implementing one science unit using the AST framework. I used multiple data collection instruments to qualitatively interpret the teachers' experiences in a naturalistic setting. Rossman and Rallis (2017) describe qualitative research as "a broad approach to the study of social phenomena...conducted in natural settings rather than in controlled ones" (p. 6). I used these data to develop a contrastive case study that deeply investigated the experiences of two educators in order to illustrate the complex impact on all participants (Stake, 1995). In this chapter, I provide contextual information on the overarching project, as well as the location and participants of my research. I position myself as a researcher and provide an explanation and rationale for the approaches I implemented. For protective purposes, I use pseudonyms in referring to all participants, schools, and programs.

Background

This study was supported by an NIH-funded project dedicated to using AST to deliver public health education about mosquitoes and promote community awareness. Throughout this paper, I will refer to this project using the pseudonym, Public Health Project (PHP). The PHP served youth in informal educational afterschool and summer camp settings in the communities and schools in which I performed this study. My specific research expanded the broader project's work to examine how elementary teachers in the formal school setting respond to a PLC targeting AST as an alternative to their current science practices. Since the broader project and this specific study involve youth and teachers in racially/ethnically diverse and socioeconomically-stressed settings, the intended impact of my work was to improve science education outcomes for those who have been historically-excluded from trajectories in science. The importance of the research around the PLC lies in understanding how we can best support elementary teachers in implementing enhanced science pedagogy toward the goal of interrupting the reproduction of educational disparities as we strive toward the societal goal of broader professional STEM representation and socioeconomic equity.

To this end, as a Graduate Research Assistant of the PHP and facilitator of the PHP-PLC, my work helped achieve two of the NIH project's overarching goals: 1) Historically-excluded youth will develop their authentic science knowledge and curiosities, as well as positive identification and motivation to pursue further studies in science; and 2) Educators will demonstrate abilities to implement authentic science teaching practices using culturally responsive methods. The PHP's focus on enhanced science teaching and learning reinforced the college access goals of Midwestern University's promise partnership, *proMise yoU,* that served the students of the two participating elementary schools by providing tuition awards for future undergraduate enrollment. The science knowledge, skills, and dispositions, developed through the theme of mosquitoes and public health, were understood by project leaders to aid students in advancing along a college-going trajectory. Pre-service teachers who participated in the PHP's teacher education work were placed at the two *proMise yoU* schools for their practica and paid as educators in the annual summer camp. In this way, my connection to the PLC schools, teachers, and students predated the specific work of this research.

My participation in the PHP and *proMise yoU* facilitated this study by aiding in the recruitment process through my previously-built relationships. Before starting to develop the PHP-PLC, my prior involvements allowed me the opportunity to form connections with some of the teacher participants. I worked directly with two of the participants as a mentee pre-service teacher. I also gained experiences prior to the start of the study through PHP community programming that were valuable to the recruitment process in establishing my expertise with AST. These opportunities familiarized me with school policies and expectations, and with community demographics. They also provided me the chance to build relationships with school staff, students, and community members, all of which were beneficial to recruiting teacher participants as I was felt to be a trusted university representative, one with something valuable to teach others about providing rigorous and culturally-responsive science instruction.

Schools and Communities

The PHP served two Midwestern, K-5 urban public schools that were partnered with the university in the *proMise yoU* program. I will refer to them using the following pseudonyms throughout this paper: Anara Elementary School (School A) and Baya Elementary School (School B). These schools are part of the Midwestern state's largest city and are two of approximately forty elementary schools in the district. They are located less than two miles away from the downtown area and are within one mile of each other. According to the Midwestern urban public-school district's 2017 performance report, which I do not cite for identity protection purposes, around 3/4 of the K-12 students are eligible for free or reduced-price lunches and about 1/4 of the elementary students are labeled as English Language Learners. However, these statistics are drastically higher for the two schools in this study as shown in *Table 3.1* below, which demonstrates variance even within the district.

Each school has a website where they include their philosophies and expectations. I do not include citations for these school websites for identity protection purposes. On the Anara Elementary School website, there is a list of behavioral expectations. These include following directions, walking while in school, keeping your body to yourself, using kind words, and taking care of property. Baya Elementary School's website provides a philosophical description. This explains their determination to implement rigorous education and beliefs that every person in the school is gifted, tenacious, resilient, and intelligent (has GRIT). When entering each school, I noticed that both buildings had posters in the hallway expressing the importance of "growth-mindsets," which contrasts to "fixed-mindsets." Originally coined as a term by Carol Dweck, someone who has a "growth-mindset" believes that intelligence can always be developed rather than it already being determined or "fixed" (Claro, Paunesku, & Dweck, 2016). This is an important distinction, given the purpose of my research, one which I will return to later.

Demographics and Performance

Although these public schools are closely located to one another, the student demographics and overall academic performances differ slightly. I created Table 3.1 (shown below) to compare the two schools. I used information from the Midwestern state's government website that keeps track of individual schools' performances for the purpose of ensuring accountability under the Every Student Succeeds Act (ESSA). In order to protect the anonymity of the schools, I do not provide a citation for this website. Some clarification of measures in *Table 3.1* is needed. The percent of students labeled as having low socio-economic status is based on the number of students who are receiving free or reduced lunch. The overall performances of the schools are determined by multiple performance measurements, including statewide standardized test scores, student achievement growth, and progress toward English proficiency. Based on my experiences at the schools, I do not understand these statistics to provide a complete understanding of the schools nor the students' performances. I provide these statistics to show how these schools are situated vis-à-vis what the state considers as proficient, but I want to emphasize the importance of being critical when viewing these numbers because reality is complex and, therefore, cannot be generalized and captured through quantified representations.

Table 3.1 Participating schools' demographics and performance statistics (2018/2019)

State-reported Demographic and Performative Statistics	**School A – Anara Elementary School**	**School B – Baya Elementary School**	**Statewide Average**
Student enrollment	300	515	-
Race	Black: 45.7% Hispanic: 34.3% White: 8.7% Asian: 7.7% Multi-Racial: 3.3% Native American: 0.3% Hawaiian/Pacific Islander: 0%	Black: 47.2% Hispanic: 31.1% White: 7.6% Asian: 8.5% Multi-Racial: 4.7% Native American: 1.0% Hawaiian/Pacific Islander: 0%	Black: 6.4% Hispanic: 11.1% White: 75.1% Asian: 2.5% Multi-Racial: 4.2% Native American: 0.4% Hawaiian/Pacific Islander: 0.3%
Students with disabilities	11.0%	12.2%	12.7%
English Learners	38.0%	42.9%	6.5%
Low Socio-economic status	98.7%	97.5%	43.0%
Overall performance of school	42.33	44.13	54.94
Percent of students scoring proficient or above in English Language Arts on the Midwestern statewide assessment	20.28%	34.55%	69.81%
Percent of students scoring proficient or above in math on the Midwestern statewide assessment	26.57%	36.59%	70.16%
Percent of students in 5th grade who are meeting the proficiency achievement benchmark in science	8.16%	8.75%	57.06%
Percent of licensed staff that are retained	44.4%	93.2%	86.9%

Schools' Approaches to Science Education

Both Anara and Baya Elementary School are in the same district, so they follow the same chronology for teaching the state-mandated Next Generation Science Standards. A major reason for this is to support students who move from one school to another within the district so that they will be able to continue learning where they left off. However, this plan is not always followed as demonstrated by the four PHP-PLC teams who each had to slightly change the schedule due to other influential factors (i.e. scheduling conflicts, time constraints, outside programs complementing other learning standards, weather conditions, etc.). As reading and math are the heavily-pushed subjects, science is not taught as frequently. The district-wide plan has science instruction rotating with social studies so that they are each taught for half of the school year. Although the daily teaching schedules vary per team, the generally allotted time for science instruction, when it is taught, is about forty-minutes three to four times per week.

Another important factor to note when describing the science education context for the participating schools is the district-adopted curriculum that has been utilized for over a decade with edition upgrades: Full Option Science System (FOSS). According to the FOSS website, it is a K-8 research-based science curriculum that uses the Next Generation Science Standards (NGSS) and "bridges research and practice by providing tools and strategies to engage students and teachers in enduring experiences that lead to deeper understanding of the natural and designed worlds" (Full Option Science System, 2020). Each teacher is provided with a "Teacher Toolkit" that includes an "Investigations Guide," a "Teacher Resources" book, a student book, and an equipment kit. The participants explained that each teacher's equipment kit has between six to eight large boxes containing both perishable and reusable materials. Online training modules are offered to the teachers for each edition upgrade, but the participants indicated that, otherwise, they are not provided extensive professional development opportunities focused on science education.

Participants

The PHP-PLC consisted of four separate teaching teams from the two schools. All participants are white women and general information for each teacher, whose names are pseudonyms, can be found below in *Table 3.2*. Two of the teams came from the Anara

Elementary School: a fourth-grade teaching team and a fifth-grade teaching team each comprised of three general education teachers. There were also two teams at Baya Elementary School: a fourth-grade teaching team with four general education teachers and three English as a Second Language (ESL) teachers, as well as a fifth-grade teaching team with four general education teachers. Each of the four teams met at separate times of the week directly after school for one hour twice per month. Of the seventeen participating educators, five of the teachers either opted out of the research aspect or did not provide full datasets; therefore, I limit the findings of this study to twelve participants' experiences with the PHP-PLC. In the course of implementation, I had an approach to data collection that separated the participants into two tiers, which I describe later.

Table 3.2 Participating teachers' professional experience and PHP-PLC teammates (2018/2019)

School	Team Name	Grade	Participant Pseudonym	Years of Licensed Teaching
School A – Anara Elementary School	Team A4 - One Woman Show	4th	Michelle	7 years
	Team A5 - Newcomers	5th	Callie	1 years
			Emma	3 years
			Holly	18 years
School B – Baya Elementary School	Team B4 – Seasoned Squad	ESL	Taylor	17 years
			Diana	19 years
		4th	**Brandi**	2 years
			Samantha	6 years
			Farrah	8 years
	Team B5 – Resisted Reinvention	5th	Danielle	1 years
			Peyton	3 years
			Kourtney	13 years

*Note: The Tier 2 participants of the contrastive case study are bolded.

Protection of Human Subjects

The Midwestern University is a federally funded research institution, which requires all research involving human participants to be reviewed and approved by the Institutional Review

Board (IRB). Prior to applying for IRB approval for this research, I completed training on the protection of human research participants through the Collaborative Institutional Training Initiative (CITI) program. Other team members working on this research study were also required to complete the training, including additional key personnel and faculty supervisors. As part of thesis work for my Master's program, one involving a naturalistic educational setting with a focus on adults, I submitted an exempt IRB application as the Principal Investigator through the Midwestern University's electronic application submission platform, IRBManager. The application was accepted and can be found in Appendix A. Before the beginning of the PHP-PLC, I provided the participants with a Conflict of Interest form and Consent form to read and sign prior to engaging in the research portion of the professional development experience.

Recruitment

Once the Institutional Review Board and schools' administration leaders approved of the intervention and research, I began the recruitment process by creating a flyer aimed at the fourth- and fifth-grade teacher teams of both Anara and Baya Elementary School. I gave the teachers these flyers during the annual "welcome back" and update sessions where I also presented a brief explanation about the PHP-PLC. As I mentioned in the "Background" section of this chapter, the recruitment process for the PHP-PLC was connected to previous interactions I had with a few of the participants long before the intervention began. Specifically, I was a practicum pre-service teacher for one of the educators in Team A4 at Anara Elementary School, as well as for Samantha at Baya Elementary School. I believe my relationships with these teachers played a role in the voluntary involvement of other educators.

Alongside these previously built relationships, there were other motivating factors for participants to join the PHP-PLC. Other incentives for teachers to participate that I mentioned during the "welcome back" session included, but were not limited to, a $1,000 honorarium, two credits toward licensure renewal through the local Heartland AEA, access to science teaching materials (i.e. microscopes, Petri dishes, live insect specimens, etc.) and the opportunity to learn and implement a student-centered science pedagogy. After the initial recruitment meeting, I reached out to the four teacher teams via email to see if they were interested in participation and to set up a meeting to discuss a tentative agenda for the year-long PHP-PLC (Appendix K). This agenda required for teachers to participate in a total of 30 hours, which included meetings, interviews, reflections, and observable lesson implementation. All four of the teacher teams confirmed and chose to participate. They agreed to the time requirements for the honorarium, and those who assented to the research portion signed both a conflict of interest and consent form.

Tier 1 Participants

As mentioned earlier, I selected Tier 1 participants because their data set was complete. Data collection in the first tier consisted of pre- and post-intervention belief and practice surveys, two mid-surveys for progress monitoring and reflective purposes, pre- and post-semi-structured interviews, and audiotaped records of the hour-long biweekly meetings of the PHP-PLC teacher teams at each school site. Twelve of the seventeen participating teachers completed these requirements, which made them eligible for Tier 1 data analysis. Here I briefly describe each Tier 1 participant as a member of their respective PHP-PLC team.

Team A4 – One Woman Show

The fourth-grade PHP-PLC team at Anara Elementary School was comprised of three general education classroom teachers. Michelle, the most experienced of the three, was the only one from her team to complete the requirements for Tier 1 data analysis. She has taught at the school for the majority of her teaching career and recently moved from first to fourth grade. When asking her about science education, Michelle mentioned feeling like she does not really understand the content; however, during the PHP-PLC meetings, Michelle often led the discussions and showed the most enthusiasm for the science content that we focused on. Team A4 created a two-week-long science unit focused around plant and animal structures and functions. The PHP provided extra materials – live insect specimens, forceps, probes, etc. – and support for implementation during selected lessons because the topic aligned with the PHP curriculum. Compared to the other PHP-PLC teams, Team A4 had a slower pace when engaging with the Ambitious Science Teaching framework and creating their science unit as they were still diving into learning the practices late in the year while other teams were finishing planning their activities.

Team A5 – Newcomers

The other PHP-PLC team at Anara Elementary School was comprised of three fifth-grade educators, all of whom were new to the school district and met the Tier 1 data analysis criteria. Callie, Emma, and Holly had a wide range of teaching experience – one, three, and eighteen years – but shared the unique situation of being unfamiliar with their school context. Callie was starting her second year of teaching and had previously been involved with facilitating a science summer camp. Emma had recently moved from another Midwestern state and taught fifth-grade math and science her first year as her school was departmentalized. Holly, one of my contrastive case study participants, had the most teaching experience of the group and spent two years of her career as a gifted and talented educator. The team developed a two-week-long AST science unit focused on matter and energy in living systems. Team A5 was quite enthusiastic about participating in the PHP-PLC. They demonstrated this by indicating that they would like to continue meeting during the next school year if it were offered again.

Team B4 – Seasoned Squad

Team B4 was the largest PHP-PLC group, which had seven teacher participants – four general education and three ESL educators. One general education and one ESL teacher did not meet the requirements for Tier 1 data analysis. The two ESL Tier 1 participants, Taylor and Diana, both had many years of teaching experience and served all K-5 grade levels. Baya Elementary School implemented a new plan during the first half of the 2018-2019 school year where an ESL teacher was assigned to one fourth- and one fifth-grade classroom during the daily science instruction time to assist the general education teacher in facilitation. This was the motivating factor for the ESL team to join the PHP-PLC. Even though this co-teaching plan was cut short due to scheduling conflicts, the ESL educators continued to participate in the PHP-PLC. Out of the four general education teacher participants, three had complete datasets: Brandi, Samantha, and Farrah. Brandi, the other case study participant, was starting her third year of teaching and had recently taken multiple graduate courses on STEM education. Similar to the ESL teachers, Samantha and Farrah had been teaching at Baya Elementary School for many years making Team B4 the most experienced and school context-accustomed PHP-PLC group. Samantha had been teaching for a total of six years – five years at this school – and was quite familiar with the PHP as she was an educator at one of their science summer camps. Farrah had the most teaching experience of the fourth-grade group and used to be in charge of ordering science materials for the whole school before the system required for teachers to order on their own.

Team B4 was the most ambitious PHP-PLC team when it came to incorporating AST as they created one and a half science units using the framework. The complete science unit was a month-long and focused on plant and animal structures, functions, and systems. Similar to Team A4, the PHP provided extra materials, including microscopes and insect specimens, and support during a few of their lessons because the topic aligned with the PHP curriculum. The team was often on-task and productive during the PHP-PLC meetings. They were enthusiastic about participating in the project and informed me, as did Team A5, that if the PHP-PLC was offered again, they would like to continue meeting.

Team B5 – Resisted Reinvention

The final PHP-PLC team was the four fifth-grade teachers at Baya Elementary School. Three of them met the criteria as Tier 1 participants. Team B5 educators had a similar range of experience as Team A5 where two of the participants were relatively new, and one had many years of licensed teaching. Danielle, the teacher who inspired the vignettes that begin each of this thesis' chapters, had one year of prior teaching experience and was new to the school. Peyton was starting her fourth year as a teacher and was enrolled at a local graduate college working toward her master's degree in culturally proficient curriculum and instruction. Kourtney had the most experience with thirteen years of teaching, and she often led the PHP-PLC meeting discussions. Although the ESL participants – Taylor and Diana – were part of Team B4, they also assisted the fifth-grade team during science instruction for the first half of the school year. Team B5 developed and implemented a three-week-long science unit using the AST framework focused on matter and energy in livings systems. The team incorporated more activities that they had used in prior years into the AST science unit compared to the other PHP-PLC teams.

Tier 2 Participants

In choosing Tier 2 case study participants, I relied on multiple deciding factors: (1) having additional data materials, such as pre- and post-PHP-PLC lesson observations and participant reflections on one of their video-recorded AST science lessons, (2) being highly interested in improving science teaching practices and motivated to participate in the PHP-PLC, and (3) participating as a member of a highly motivated and enthusiastic PHP-PLC team.

Additionally, I wanted to examine two participants with contrasting professional backgrounds in order to see how their differing prior experiences influenced their participation outcomes.

With respect to deciding factor (1), I was able to conduct pre- and post-PHP-PLC lesson observations with nine of the participants, seven of which agreed to complete the additional data collection measurement of recording and reflecting upon one of their AST science lessons. These additional data resources assisted in understanding the case study participants' experiences. With regards to (2), a major contributing factor to successful and high-quality professional development outcomes is the motivation level teachers possess during the intervention. Professional development interventions that required teachers to participate have been found to be significantly less successful than interventions with teachers who volunteered themselves (Kennedy, 2016). There were a few teachers who demonstrated a lack of motivation to participate through either lower meeting-attendance, verbally stating they were participating in order to receive the honorarium, and/or verbally expressing they were attending because they felt obligated since others were participating. In terms of (3), along with the Tier 2 participants' individual motivation levels, I accounted for the collective motivation and enthusiasm levels of their participating team members because it affected the overall productivity and attitudes toward the PHP-PLC. For example, the fourth-grade team at Anara Elementary School – Team A4 – consisted of two members who had low attendance and often expressed a lack of motivation, which led to low productivity during the PHP-PLC meetings; therefore, I chose to eliminate these participants as candidates for Tier 2. The literature suggests that the beliefs of colleagues are significant influences on individual teachers' beliefs, so I narrowed potential Tier 2 participants by analyzing the teams they were part of. A 2012 study conducted on the effects of elementary teacher's beliefs on science teaching found that they were heavily influenced by their colleagues. The authors write, "Teachers indicated that time and resources were barriers, but the opinions of others and school mandates were the most closely aligned to their emerging practice" (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012). Also, Tschannen-Moran, Hoy, and Hoy (1998) discussed in their extensive review on the meaning and measures of teacher efficacy that low efficacy around teaching may be transferred between school staff, which can lead to an overall negative climate that affects students' learning outcomes and teacher retainment.

I also narrowed down the case study candidates by selecting educators with unique professional backgrounds to compare and contrast in order to understand how the PHP-PLC affected their science teaching identities. After applying the deciding factors to the Tier 1 participants, I determined that two teachers met the criteria for Tier 2 analysis. The first Tier 2 case study participant is Brandi, a third-year teacher on the fourth-grade team – Team B4 – at Baya Elementary School. The second Tier 2 case study participant is Holly, a nineteenth-year teacher on the fifth-grade team – Team A5 – at Anara Elementary School. I describe both Tier 2 participants' context, professional backgrounds, and experiences in more detail when I present the contrastive case studies in Chapter 4. The purpose of comparing and contrasting these case studies is to provide a more intimate perspective on how the PHP-PLC affected participants' science teaching identities as individuals and in respect to their contexts. Considering this interpretation comes from my own analysis and understanding of what the teachers' reported, I will explain my personal position as a researcher and participant of this study to provide background on the identity and philosophical ideology that influences my interpretation.

Methodology

This is a qualitative study with a contrastive case study methodological approach. My philosophical assumptions, or ontological and epistemological orientations, influenced the design of this study. Creswell and Poth describe ontology as "the nature of reality" and epistemology as "what counts as knowledge and how knowledge claims are justified" (Creswell & Poth, 2018, p. 20). I have a constructivist ontology, which means that I believe reality does not exist outside of people's social construction of cognition. I have an interpretivist epistemology which means that I believe "social processes are continually created by human interpretation" (Rossman & Rallis, 2017, p. 39). Thus, I interpreted the participants' experiences by analyzing their responses and actions as revealed through the data instruments in order to see how the PHP-PLC affected their science teaching identities. My purpose is not to claim or assert a universal Truth in the findings; I aim to describe and make sense of the participants' experiences, drawing from the data, and use that to assert situated truths from these cases that may hold for similarly-contextualized science educators and instructional settings.

Rather than framing my methodological strategies using reliability and validity, I am utilizing trustworthiness and credibility, which correspond with my constructivist-interpretivist lens. Trustworthiness may also be referred to as dependability or confirmability (Creswell & Poth, 2018). Rossman and Rallis (2017) characterized a trustworthy study as one that uses systematic, intentional, and transparent research practices as well as applies "rigorous reasoning" through ethically-sound processes (p. 60). As for credibility, Maxwell (2013) provides many strategies to address "validity threats." These strategies are long-term involvement, rich data collection, triangulation, and incorporating quantitative data. I spent many hours with each PHP-PLC team throughout the 2018-2019 school year, including the fifteen one-hour meetings, lesson implementations, observations, and interviews. I collected data using a variety of instrument types, which I describe in the Data Collection section. Using these different data tools contributes to the credibility of my study because it offers for triangulation of rich data, both numerical and descriptive.

Triangulation was originally identified as one of four types of validation by Patricia Lather. She describes triangulation as referring to many data instruments, theories, and methods (Lather, 1991). Rossman and Rallis (2017) explain that triangulation "helps ensure that you have not studied only a fraction of the complexity that you seek to understand" (p. 65). In addition to the interviews, observations, reflections, and open-ended survey questions, I decided to include numerical surveys to aid in triangulating the data analysis process. I do not use these survey results in the typical quantitative manner with statistical analysis. Instead, I applied basic "quasi-statistics," which Maxwell, referring to Becker's (1970) original definition, describes as "simple numerical results that can be readily derived from the data" (Maxwell, 2013, p. 128).

In the book, *Qualitative Research Design: An Interactive Approach*, Maxwell (2013) describes that the research instrument in qualitative studies is the researcher themself. Even though I utilized multiple tools to gain an understanding of the participants' perspectives, I am ultimately the interpreter of the gathered information. In addition to being the interpreter, I played a participatory role that influenced other participants' experiences based on our previously built relationships, interactions, identities, and so on. Therefore, if another researcher were to implement this study, they would have different experiences and conclusions.

My constructivist and interpretive philosophical and methodological approaches require acknowledging my subjectivity, making me part of the study. My personal perspective and identity played a crucial role in the participants' experiences and how I interpreted those experiences. What this means is that because it is constructivist, interpretive, work I am part of the situation that I am examining; therefore, I need to reveal my positionality. I do this in the following section.

Positioning Myself as a Researcher

I am a 23-year-old white woman who is working toward a Master of Science degree in education with an emphasis on social and cultural studies. I was raised in a low-income, single-parent household in a small Midwestern town, and I am a first-generation academic. I have seen the influential power of education in my own life's trajectory and am passionate about playing a role in other's educational experiences. I have been interested in culturally- responsive science teaching for over three years, which developed in my undergraduate studies as an elementary education major, where I earned an endorsement in science teaching. It was during this time that I started my journey with the PHP. I began as a student enrolled in the PHP's college course which introduces pre-service teachers to AST and to Diversity Pedagogy Theory (DPT) – a set of principles developed by Hernandez-Sheets (2004) that illustrate pedagogical behaviors that demonstrate culturally inclusive practices. After completing the course, I continued my participation with the PHP as a part-time employee and later transitioned to my current role as the Graduate Research Assistant. Throughout my three years of employment, I gained many valuable experiences that prepared me to facilitate the PHP-PLC, such as leading an after-school program, aiding implementation of the college course, helping develop a four-unit curriculum using AST practices, and partaking in three science summer camps as a lead educator. From these experiences, I became both familiar and comfortable with planning and facilitating lessons using the AST framework.

I am interested in doing this work because I believe there are many injustices in our society that can be rectified through meaningful, equitable education. When I say, "meaningful education," I am not referring to reforming the current education system, but rather, disrupting and transforming it in order to be meaningful to different cultures and customs instead of only serving the dominant narrative. I believe that the education system in the United States was created to and continues to perpetuate the oppression of marginalized groups, so it is incapable of being equitable in its current state. My perspective is that high-quality educator training in culturally responsive science teaching is one of the necessary elements for transforming the oppressive education institution.

Rossman and Rallis describe perspective on practices as either *etic* or *emic*. *Etic* is an "outside" perspective, and *emic* is an "insider" perspective. They state, "Because fully representing the subjective experience of the participants (the emic perspective) is an unachievable goal, qualitative researchers strive to represent clearly and richly their understanding of what they learned (the etic perspective)" (Rossman & Rallis, 2017, p. 86). Rather than thinking of perspective as binary, I think of it as a scale. My position with respect to the community, school, and research participants differ from one another in important ways, providing me both an *emic* and an *etic*, a hybrid, perspective.

Concerning the research participants – elementary education teachers – I would consider myself closer to an insider than outsider because we share a few major identity factors. Most of the participants are white women with a college degree in elementary education coming from a low to middle-class economic status. I recognize that we have many differences as well, such as our work and personal experiences, which exemplifies why no one can truly ever be an "insider" of another's truth. With respect to the community and school my study is situated in, I would consider myself more of an outsider than an insider. As a white researcher working in schools predominantly serving students of color with low socioeconomic statuses, I recognize my racial identity carries privilege that positions me as an outsider. I cannot ever fully understand nor accurately represent their experiences and perspectives. With these *emic*-*etic* considerations in mind, I focused this study on the teachers' experiences, rather than the students', as my interpretative priority.

Data Collection

The general purpose of PHP-PLC was to use AST to support participating educators' science teaching identities to be more culturally responsive and reform-based in efforts to create equitable, student-centered learning environments. In order to investigate whether the purpose of the PHP-PLC was accomplished and to answer this study's research questions, I used multiple data collection instruments throughout the school year, including pre- and post-surveys, interviews, and observations, as well as participant lesson-reflections. *Table 3.3* provides an overview of the data instruments, the research question they help to answer, and the information they provide. Both Tier 1 and Tier 2 participants completed the data instruments shown in Table 3.3; however, I only analyzed observations and reflections for the Tier 2 teachers.

Table 3.3 Data Collection Instruments' Research Purposes

Research Question	Data Collection Instrument	Information it Provides
1.a. How do Professional Learning Communities focused on a phenomenon-based science teaching framework affect elementary educators' science teaching identities: **self-efficacy**?	STEBI – A Survey	Pre- and post-surveys were administered to teachers to see the effects of the PHP-PLC on their personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE).
	Interviews	Pre- and post-interview questions (semi-structured) were designed to elicit teachers' feelings about their abilities to teach science by asking them what their goals were and what challenges they face.
1.b. How do Professional Learning Communities focused on a phenomenon-based science teaching framework affect elementary educators' science teaching identities: **beliefs**?	Field Notes	Each PHP-PLC was audio-recorded, and notes were taken to document teachers' beliefs about science education.
	Interviews	Pre- and post-interview questions (semi-structured) were designed to capture changes in teachers' beliefs by asking how they felt about science and science education.

Table 3.3 (Continued)

1.c. How do Professional Learning Communities focused on a phenomenon-based science teaching framework affect elementary educators' science teaching identities: **practices**?	SIPS Survey	Pre- and post-surveys were provided to teachers to see how frequently they incorporated specific science teaching practices in their classrooms.
	Observations	A minimum of two observations were conducted – one at the beginning of the school year and one during an AST science lesson – in order to see how the AST elements were implemented in their teaching practices.
	Reflections	After the participants implemented the AST science unit, a structured document was provided for them to reflect on each phase they planned and enacted. For those who video-recorded one of the unit lessons, I asked them to provide a brief reflection on their facilitation.
	Interviews	Pre- and post-interview questions (semi-structured) asked teachers about their science pedagogical methods and lesson structures.
2. How do these influences relate to and reflect particular school contexts and teacher characteristics?	Field Notes	Each PHP-PLC was audio-recorded, and notes were taken to document teachers' perspectives about their context-environment and the teams' relationship dynamics.
	Interviews	Pre- and post-interview questions (semi-structured) asked teachers about what professional development opportunities have been offered to them and how they felt about the district-required curriculum and teaching schedule.

Surveys

I administered a total of four different surveys throughout the PHP-PLC to assist in understanding the participants' experiences. I incorporated two research-based survey instruments into this qualitative study for general descriptive purposes rather than quantitative, statistical use due to the small number of participants. Considering this, these survey responses are accompanied with other data collection instrument findings when answering the research questions. The other surveys were ones that I created and administered through the Qualtrics system. They were comprised of open-ended questions, as well as a Likert scale for teachers to indicate their self-perceived understanding of AST components. All surveys were included in Tier 1 data analysis.

SIPS Survey

Hayes, Lee, DiStefano, O'Connor, and Seitz (2016) developed the Science Instructional Practice survey and described the purpose of the tool as measuring shifts in teachers' key instructional practices. They explain their rational for development as follows: "No existing instrument comprehensively measures both inquiry and other relevant instructional practices with clearly defined set of items. Moreover, the adoption of NGSS necessitates updated items that make explicit links to the NGSS Science and Engineering (SE) practices." (Hayes, Lee, et al., 2016, p. 138). The pre- and Post-SIPS surveys were implemented to gain an understanding of changes in participants' science teaching practices after the PHP-PLC intervention. Teachers marked how often they incorporated thirty-one teaching practices into their classrooms. They had the following options for each practice: never, rarely (a few times a year), sometimes (once or twice a month), often (once or twice a week), and daily/almost daily. The SIPS survey instrument and scoring guide can be found in Appendix B.

STEBI Survey

In order to measure the influence of the professional learning community on the participants' self-efficacy in science teaching, I utilized the survey tool, Science Teaching Efficacy Belief Instrument (STEBI), developed by Iris Riggs and Larry Enochs (1990). These researchers created the survey tool based on concepts from Bandura's Social Cognitive Theory and developed the tool to measure both personal science teacher efficacy (PSTE) and science teaching outcome expectancy (STOE), which are described earlier in Chapter 2. The instrument consists of twenty-five statements that the teachers responded to by indicating whether they strongly agreed, agreed, felt uncertain, disagreed, or strongly disagreed with each one. The STEBI survey instrument can be found in Appendix C.

Mid-Surveys

A Qualtrics survey was sent to the PHP-PLC participants near the middle of the 2018-2019 school year. The survey had three purposes: (1) to repeat questions from the Pre-Interview that focused on their beliefs and practices in science teaching, (2) to gain an understanding of how familiar they were with each phase of AST, and (3) to obtain feedback on the PHP-PLC meetings in order to alter the approach to best fit participant needs.

Pre-Unit Surveys

Another Qualtrics survey was sent to the PHP-PLC participants prior to the beginning of their AST science unit implementation. I asked the teachers to answer the following three prompts: (1) Identify two to three of the listed, or unlisted if preferred, AST practices you want to set as a goal/specifically want to implement during the science unit (2) List your particular goals for your students – science knowledge, attitudes, beliefs, practices, etc. – for this unit (3) List your concerns/worries/challenges for this unit. I copied these responses into their final reflection documents to remind them of their thoughts prior to teaching the AST science unit.

Interviews

Before creating interview protocols, I searched the literature for information about interview types and methodologies. Many of the articles I read provided either steps or checklists for "good" interview techniques. Notes on these techniques can be found at the end of the document in the "Appendix" section. Overall, I learned that it is essential to use a script when conducting interviews in order to keep the dialogue focused. The scripts/protocols do not need many questions; however, the questions must align with the research question and should be open-ended (Castillo-Montoya, 2016). A common technique, which was also mentioned in the course texts, is to begin questions with "tell me about" in order to create space for the interviewee to speak freely (Jacob & Furgerson, 2012).

Other than interview techniques, I learned about different interview methods: structured, semi-structured, and open-ended. After viewing different research studies that relate to my own, I found that the most common interview method in small-scale qualitative research is semi-structured (King, Shumow, & Lietz, 2001; Levitt, 2002; Adamson, Santau, & Lee, 2013). This type of interview has open-ended questions prepared that allow for the interviewee to answer and elaborate in a freer manner; however, there are still beginning, middle and end topics the interviewer sets out to talk about (Seidman, 2006). I also learned that it is common for researchers in my field to include the interview protocols into their articles; therefore, the pre- and post-interview protocols used in this study are located in the appendix. During the pre- and post-interviews, I audio-recorded participants' responses in order to transcribe them. I created a separate document for each interview and transcribed the questions and answers.

Pre-Interviews

I conducted pre-interviews during the beginning of the school year in order to learn about the participants' professional background, as well as their current self-efficacy, beliefs, and practices in science teaching. I scheduled the pre-interviews with individual participants for twenty- to thirty-minute time slots and met them in a quiet location at their school. The protocol for the pre-interviews is located in Appendix E.

Post-Interviews

I conducted post-interviews with each of the participants once the PHP-PLC ended. I individually scheduled the post-interviews for anywhere between forty-five minutes to one hour. During the final interview, I provided each participant their pre- and post-surveys with notes on areas that changed. We discussed their perception of why those areas changed, which provided insight on their reflective processes. The post-interview protocol can be found in Appendix F.

Observations

I observed nine of the participating teachers at least two times during the school year, once at the beginning and once at the end. I selected teachers based on how our schedules aligned and if they were able to implement the AST science unit. For instance, ELA participants were no longer co-teaching during the second half of the school year due to schedule changes, so I was unable to conduct final observations with them. Also, I was unable to observe a few participants at the beginning of the year because of availability conflicts, so I did not complete a final observation with them either. For the nine selected teachers, the first observation was conducted to gain a sense of the classroom environment and climate, teacher practices, and student demographics. The last observation was conducted during one of the AST science lessons. During this observation, I had the targeted lesson readily available and documented any changes made by the educator. The purpose of these observations was to gain a sense of how the PHP-PLC impacted the participants' science teaching practices.

Reflections

During the final PHP-PLC meeting, the participants reflected on their AST science unit implementation. I provided a template that was organized by AST phase and had designated areas for teachers to note any prominent differences between the corresponding targeted versus enacted lessons, as well as any strengths, challenges, and AST moments they experienced during enactment. There was an additional location for the participants who videorecorded a lesson to reflect on what they noticed when they watched it. The reflection document was adjusted for the ESL teachers by replacing the AST moments with ESL connections. I customized each participants' reflection template prior to administration by pasting in their Pre-Unit survey responses in order to remind them of the goals they set.

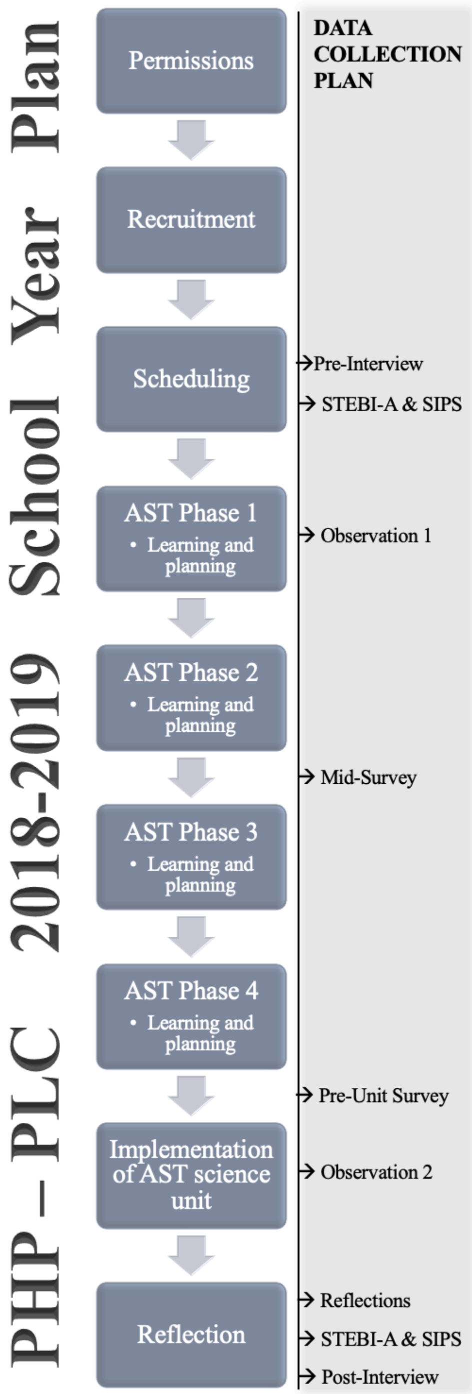

Figure 3.1 PHP-PLC plan for the 2018-2019 school year.

Procedure and Analytic Plan

The purpose of this section is to describe the execution of the PHP-PLC using the general procedure I followed. However, it is important to note that I sought to be responsive to the teachers' needs, so this scope and sequence played out slightly differently for each team. For example, Team A4 had not progressed as far as expected with the AST readings, which required us to use a jigsaw method where each participant was assigned a phase to become the "expert" on and then share the important components with the rest of us during one of our meetings. The other PHP-PLC teams had a progression pace that allowed for each participant to complete the AST readings and become individually familiar with the phases. This is just one example of how a team's progression differed, but each had their own distinctions. During the analysis, some of these differences are considered when answering the second research question about how context was connected to the participants' experiences with the PHP-PLC.

The PHP-PLC plan was that throughout the school year, each team would meet for one hour twice a month. All four of the PLC teams decided to schedule the meetings for a set day of the week immediately after school hours. For example, Team A5 met every other Monday from 2:45-3:45 p.m. There were a few incidences of when the meetings had to be rescheduled due to weather conditions and unexpected circumstances; otherwise, the set schedule was followed throughout the year. Once I had completed my recruitment process and I knew who was participating, I set up three-ring binders for each teacher that was organized using multiple tabs that sectioned off each AST phase. I also provided an ambitious, tentative timeline that described the hourly expectation and general PHP-PLC meeting schedule, which can be found in Appendix D. Prior to each PHP-PLC team meeting, I wrote out a detailed plan in a running document for what I hoped we would accomplish, which differed from my initial meeting goals and timeline expectations. Before intervention implementation, I consulted with two members of the AST development team – Carolyn Colley and Cristina Betancourt – to gain their coaching advice. They offered ideas on how to organize the PHP-PLC team meetings and provided me with related research articles. Along with these resources, I also explored components of research-based professional development opportunities and sought out coaching tips, which aided in the original design I created for the PHP-PLC meetings.

From what I gathered as effective coaching strategies, I developed general goals for the fifteen PHP-PLC meetings (See Appendix K). These aimed for open discussion during the first five to ten minutes and review of an AST component for the next ten to fifteen minutes. I then planned for a flexible space on the agenda afterward and, finally, dedicated the last five to ten minutes for debriefing and discussing the next meeting. Considering I had less classroom teaching experience compared to the PHP-PLC participants, there was an unusual dynamic because stereotypically, professional development interventions are led by “expert” coaches.

Therefore, I viewed and represented myself as a resource provider and discussion prompter rather than an expert in AST. I informed the participants of this, told them we were learning alongside one another, and explained that I was there to support them in whatever way possible. A valuable resource we utilized often was the book, *Ambitious Science Teaching* (Windschitl, Thompson, and Braaten, 2018), that the PHP provided to each participant. I prepared for the PHP-PLC meetings by highlighting important sections of the book and printing off resources from the AST website for teachers to add to their binders. I also created Google Documents for each team to collaboratively develop their science unit plans on. Before each PHP-PLC meeting, I sent the teams an email with both a tentative agenda and the goals we established previously in order to aid us in accomplishing the overarching learning and planning objectives. I documented the plans and notes for each PHP-PLC meeting (See Appendix I for an example).

As for the general scope and sequence of the PHP-PLC meeting topics, I originally planned for the first five meetings to be focused on diving into the four core practices of AST, the next five meetings dedicated to planning the AST science unit, and the final five meetings devoted to implementation reflection and adjusting lessons based on student responses. However, the meetings evolved into the teachers learning the AST phases as they planned the science units. For example, the teams completed readings and discussions over AST Phase #2 – Eliciting Students' Ideas – and then planned the part of the science unit that corresponded with that phase. In order to support the teachers during their unit planning, I slightly adjusted the AST practices to fit a more familiar pedagogy – the 5Es – and added these altered lesson templates into each teams' planning document. I provide the adjusted template for the third phase of the AST framework in Appendix J. We ended up not having enough time to analyze student responses for lesson adjustment purposes. However, each team achieved the goal of developing and implementing a full AST science unit.

Each team taught their completed AST science units near the end of the 2018-2019 school year. During this time, the PHP-PLC meetings were focused on finalizing lessons and preparing for implementation. A majority of the teams prepared for the science lessons by creating digital slideshows with visual aids, printing off student resources, and gathering necessary materials. The PHP lent the teams science tools for their lessons, including microscopes, insect specimens, forceps, petri dishes, etc. Teams A4 and B4 had a few lessons that required assistance from PHP members, which included help from myself, the program coordinator, a pre-service teacher, and a community educator. Otherwise, the majority of the AST science units were taught solely by the participants. Once the units were finished, any remaining PHP-PLC meetings were spent reflecting on the student achievement outcomes and participants' teaching experiences. I gathered the final surveys and interviews, expressed my appreciation for their participation, and said my goodbyes in anticipation of collaborating with them again during the next school year. The PHP was unable to extend the PHP-PLC as a two-year professional development program, but we continued to offer support and resources at the request of the participants.

The next phase involved organizing and analyzing the data. I created an Excel spreadsheet and inputted all the data for each participant, so that I could easily compare the results. This included survey calculations and open-ended responses, interview transcriptions separated by question, and observation notes. For numerical data, I assigned colors to the pre- and post-survey results based on whether they increased or decreased. I compared each teacher to the overall average and took note of any significant findings. For descriptive data, I highlighted important words and found themes for each interview/open-ended survey question. I provide an example of this in Appendix G.

My plan was to use information from these instruments to create the contrastive case studies in reference to the broader experiences of Tier 1 participants. I reviewed the findings for Tier 1 to gain a general understanding of how the PHP-PLC affected the participants' science teaching identities and how they may have been influenced by their context. I narrowed in on the similarities and differences in Tier 2 participants' experiences by creating case study profile documents where I compiled and analyzed their individual data results, resulting in information-intense twenty-page documents. I provide an example of how I organized the case study profiles in Appendix H. In the next section, I present a broad contextual overview of general Tier 1 findings. I then present my contrastive cases to answer the research questions in narrative form.

CHAPTER 4. FINDINGS

During a PHP-PLC meeting I had with Danielle and her team soon before they began their science unit, I learned that the entire 5th grade class sat with Baya Elementary School's administration to discuss behavioral expectations (Meeting Notes, April 8th, 2019). Danielle expressed to me that she was having difficulty with classroom management and found it challenging to engage the students. She revealed to me in her final interview, "I don't know what to do to get them to pay attention. I could stand on my head in the front of the classroom, and they'd just ignore it" (Danielle, Post-Interview, May 21st, 2019). I recalled how she was concerned about falling into her normal teaching ways, so I observed her implementing one of lessons we planned in our science unit. I noticed that Danielle utilized a teacher-centered approach by giving out answers through lecturing rather than asking the open-ended questions we prepared. A majority of students were disengaged and off topic (Observation, May 21st, 2019). She told me this reflected how the whole school year went and that, prior to this lesson, she was absent for a large portion of the earlier activities in the unit, so the students did not receive much of the planned learning (Danielle, Reflection, May 22nd, 2019). According to Danielle's pre- and post-STEBI (November 19, 2018; May 21st, 2019) and SIPS (January 14th, 2019; May 21st, 2019) surveys, she had the largest self-efficacy decrease and the lowest reported amount of science instruction. Danielle explained, "It's so frustrating to me and I know that they know I'm a new teacher and...I'm not saying I'm good at everything obviously, but...from the beginning of the year, I really struggled. Even some of my kids who have always paid attention are starting to mess around, and I think they've kind of given up because it's just so loud in here and most of the class is doing whatever they want, running around, throwing stuff across the *class. I mean, it's an all-day long thing. It's exhausting" (Danielle, Post-Interview, May 21st, 2019).*

Unfortunately, the PHP-PLC was an unsuccessful science-instruction intervention for Danielle as many other elements played a strong role in her teaching experiences. However, this was not true for all participants. Understanding the interplay between the goals of the intervention and its differential impact on teachers is the focus of this chapter. I begin by presenting major findings from the Tier 1 data analysis, which includes the twelve teacher participants who had complete data sets. I paint a broad picture of how components related to their science teaching identities were affected by the PHP-PLC in order to set the stage for understanding the more specific experiences of Tier 2 participants – the two educators in my comparative case study. From the review of the data, I aim to answer my two research questions by analyzing the emerging outcomes of participants' responses to surveys, interviews, and reflections, as supplemented through my observation and meeting notes:

1. How does a Professional Learning Community focused on a phenomenon-based science teaching framework affect elementary educators' science teaching identities?
    a. How does it affect their self-efficacy?
    b. How does it affect their beliefs?
    c. How does it affect their practices?
2. How do these influences relate to and reflect particular school contexts and teacher characteristics?

After careful investigation of the data, I determined major themes for each of my research questions. I compiled key findings organized by research question and theme for both Tier 1 and Tier 2 participants, which are depicted in the following table:

Table 4.1 Key themes and major assertions for Tier 1 and Tier 2 participants

Research Question	Themes	Tier 1 Findings	Tier 2 Findings	
			Case 1: Brandi	Case 2: Holly
1.a. Self-efficacy	Extent of Teacher Impact (STOE)	Increase	Increase	Increase
	Capabilities to Perform (PSTE)	Increase	Increase	Decrease
1.b. Beliefs	General Science Education Beliefs	Growth-Mindset	Growth-Mindset	Growth-Mindset
	Elements that affect science teaching possibilities	Time Resources Content knowledge	Preparation Curriculum	Preparation Pedagogical knowledge
	Best practices for optimizing student achievement	Open-ended questions Student-centered	Experiments Exploration	Hands-on
1.c. Practices	Frequency	~2 hours per week Wish for more science time	Everyday	~2 hours per week
	Instructional methods	Student-centered Exploratory	Student-centered Hands-on	Student-centered Hands-on
2. Context	Peers, support, and student/teacher characteristics	Little PD in science teaching	Surrounded by experienced peers	Most experienced of group
	PHP-PLC Dynamics	Motivation, engagement, and beliefs are "contagious"	Highly motivated Highly productive	Highly motivated New to district

General Impacts of PHP-PLC on Tier 1 Participants

Although there was a total of seventeen teachers who participated in the PHP-PLC, I excluded five of them because they either chose not to partake in the research portion or they had missing data. Between the two schools included in this study – Anara and Baya Elementary School – there were four PHP-PLC groups, which I described in Chapter 3 and depict in *Figure*

4.1 below. Each group had at least one participant that qualified for Tier 1 analysis, which are represented in the figure as the dark icons. The Tier 2 participants are differentiated with a gold star on their icon.

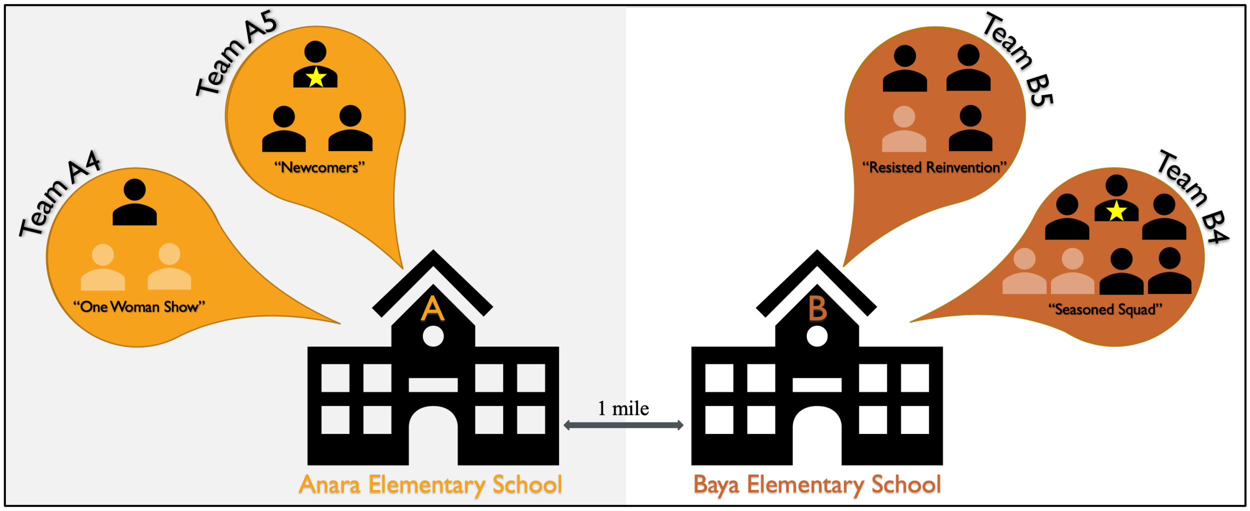

Figure 4.1 PHP-PLC participating schools and teacher teams

In order to understand how the PHP-PLC broadly impacted the educators, I analyzed interviews, surveys, and meeting notes for each Tier 1 participant. I provide an overview of individual teacher outcomes in *Table 4.2* below. Following the table, I begin explaining my findings starting with connections between contextual factors, teacher characteristics, and the PHP-PLC group dynamics, which relates to my second research question. I then dive into how the different elements interrelated with science teacher identity – self-efficacy, beliefs, and practices – changed throughout the PHP-PLC intervention, which addresses my first research question. I support these findings with evidence examples, including teacher quotes, survey results, and field notes.

Table 4.2 Overview of individual Tier 1 participant outcomes

School	Team Name	Grade	Participant Pseudonym	Years of Licensed Teaching	Context	Changes in Self-Efficacy	Changes in Beliefs	Changes in Practices
School A – Anara Elementary School	Team A4 - One Woman Show	4th	Michelle	7 years	Lack of support from peers	Lowest pre- & post STEBI survey scores	Positive	Teacher-centered
	Team A5 - Newcomers	5th	Callie	1 years	Highly motivated All new to district	Increase	Positive	Teacher-centered
			Emma	3 years		Increase	Positive	Student-centered
			Holly	18 years		Decrease	Positive	Student-centered
School B – Baya Elementary School	Team B4 – Seasoned Squad	ESL	Taylor	17 years	Highly motivated Highly productive	Decrease	Positive	Student-centered
			Diana	19 years		Increase	Positive	Student-centered
		4th	**Brandi**	2 years		Largest increase	Positive	Student-centered
			Samantha	6 years		Increase	Positive	Student-centered
			Farrah	8 years		-	Positive	Student-centered
	Team B5 – Resisted Reinvention	5th	Danielle	1 years	Added a fourth teacher Class management difficulties	Largest decrease	Negative	Teacher-centered
			Peyton	3 years		Decrease	Positive	Student-centered
			Kourtney	13 years		Increase	Positive	Student-centered

Context – More Influential than Experience

After reviewing the data, I noticed that years of experience did not determine educators' outcomes and responses to the PHP-PLC intervention. Context and teacher identity were much more influential. For example, when comparing the two novice, 5th grade teachers who both had one year of prior teaching – Danielle and Callie – their experiences differed greatly. In the vignettes at the beginning of each chapter, I described how Danielle started the year full of enthusiasm but ended with a negative outlook on the profession. As I mentioned before, both her self-efficacy and science practices declined according to the pre- and post-STEBI and SIPS survey responses. Callie, on the other hand, began with a similar self-efficacy score, but ended with a more positive mindset. She was part of Anara Elementary School's 5th grade PHP-PLC team where all three teachers were new to the district. Although her practices continued to be more teacher-centered like Danielle's, her self-efficacy and beliefs improved. When I asked her to describe her experience with the PHP-PLC during our final interview, she said:

> "After having the Ambitious Science Teaching kind of applied in science, it was like, 'Oh yeah, this makes sense. This is why they [students] need to have more hands on. This is why they need to think together'...If you put more effort in, they'll get more in return, and I'll get more in return and we'll all be more satisfied with the results" (Callie, Post-Interview, May 17th, 2019).

Also, it becomes especially clear from my Tier 2 analysis that years of experience is not a reliable indicator because the novice case study participant, Brandi, had more positive outcomes than Holly, an educator with sixteen more years of teaching.

A complex contextual factor that was a strong indicator of participants' outcomes was the peers an individual was surrounded by. Participants who collaborated in PHP-PLC groups that were highly motivated, more efficacious, and had adopted student-centered science teaching identities tended to lift one another up more effectively than those who did not. For example, Michelle – going into her 8th year of teaching – in the "One Woman Show" group at Anara Elementary School worked with two peers who were often absent and/or did not offer much input during the meetings. Michelle carried the group but did not feel confident in teaching science from the get-go and had the lowest pre- and post-STEBI self-efficacy score (Michelle, Pre-Interview, September 21st, 2018; Pre-STEBI Survey, February 14th, 2019; Post-STEBI Survey, June 3rd, 2019). Her science teaching identity did not improve after participating in the PHP-PLC. A participant who started with the same pre-STEBI self-efficacy score was Diana, an ESL teacher in the "Seasoned Squad" group at Baya Elementary School. This PHP-PLC team was highly motivated and had higher self-efficacies than all other teams. Diana's science teaching identity improved significantly, and she told me during our final interview:

> "If I became a classroom teacher again, I would definitely do the anchoring event or the overarching question...I would definitely be doing those more in science than I did before. And I would definitely find the time to have more experiments because I saw the value in that" (Diana, Post-Interview, May 22nd, 2019).

Something I found intriguing were apparent differences when comparing the participants' outcomes by school location. Although Anara and Baya Elementary Schools are only one mile apart, I noticed distinctions between teachers' practices and self-efficacy beliefs. The participants at Baya Elementary School had indicated using less traditional science teaching practices on the pre- and post-SIPS survey than those at Anara Elementary School. Teachers at Baya Elementary School also had a more significant decrease in traditional practices, more student-centered instruction, and higher pre- and post-STEBI self-efficacy scores. These findings are not statistically significant due to the small number of participants so I would have to alter my methodology to provide clearer insight on this inquiry.

Self-Efficacy – Increased Personal Science Teaching Efficacy

While still referring to the influence of context, the teachers at Anara Elementary School had noticeably lower pre- and post-STEBI survey scores on average. The case study participant from this school, Holly, was an example of having a low self-efficacy for teaching science, which I explain further in my Tier 2 analysis. Another participant from Anara Elementary School with a low-self efficacy, mentioned above, was Michelle. She discussed how with me during our final interview that she felt more confident when teaching science topics that personally interested her. Michelle's personal science teaching efficacy stayed the same, and it was the lowest out of all the participants. She talked about how she felt "ineffective" and that she was doing her students "a disservice" when teaching science. She said, "I'm not a science person. I don't understand science" (Michelle, Post-Interview, June 3rd, 2019). Although both Holly's and Michelle's science teaching self-efficacies did not improve after participating in the PHP-PLC, they did for most participants.

Two STEBI survey items that increased significantly were (#22) "When a student has difficulty understanding science concept, I am usually at a loss as to how to help the student understand it better," and (#1) "When a student does better than usual in science, it is often because the teacher exerted a little extra effort." After asking one participant to tell me about her experience with the PHP-PLC during our final interview, she responded, "It was great to have that space and time to really think about what we were doing and the questions that we were going to ask. Having that time to think about that was really helpful. I think it made the lessons much stronger, and me more confident" (Emma, Post-Interview, May 13th, 2019). Many teachers discussed how the PHP-PLC provided the planning and prepping time rarely available otherwise, which appeared to be connected to their self-efficacy beliefs. Without time to establish a deep understanding of science content and teaching practice, improving self-efficacy would be quite challenging.

Beliefs – Growth-Mindset

As I mentioned in Chapter 3, both schools emanate the philosophy of "growth-mindsets." This is when intelligence is viewed as something that can always be developed rather than something that is already determined or "fixed" (Claro, et al., 2016). Multiple participants expressed this ideology. Two examples are the following responses:

> "I want them to be ambitious and have them have an open mindset, be curious, and also be open for feedback and input, and also have a growth mindset as well" (Brandi, Pre-Interview, October 5th, 2018).

> "I have a goal for students to gain stronger understanding of the standard and information related to the standard. I want students to have a positive attitude and growth mindset about science. I want students to learn to question and that they use the scientific process frequently in their daily lives. I also want them to be intrigued by science, so they continue in science" (Emma, Pre-Unit Survey, March 25th, 2019).

Common science goals teachers had for their students related to them having a "growth-mindset." When asked during interviews what they aimed for students to gain from science education, frequent responses were related to critical thinking, ability to ask questions, building content knowledge, and being engaged with the activities. Kourtney explained during our initial interview:

> "Our main goals are active listening and doing your best and not putting other people's opinions or ideas down, handling the materials, obviously just respectfully. But really, I

> just want them to investigate and discuss. I want them to come up with whatever ideas and brainstorm that they think. And then I usually collect their brainstorm and then we dive deeper into each of those pieces because I want it to be important to them...I want them to figure that out through investigations. I don't want to just tell them or show them" (Kourtney, Pre-Interview, September 27th, 2018).

In order to meet these goals, participants often believed that student-centered, hands-on lessons were optimal. Many were aware of reform-based practices but achieving them proved difficult.

Participants indicated throughout the PHP-PLC intervention that one of the most prominent elements affecting their abilities to reach these goals was time. Almost every teacher talked about how there was never enough time to plan, prepare, and implement science instruction. They discussed how reading and math were pushed as more important subjects by policies, standardized-tests, and administration, leaving little time for science. From their responses, it became evident that time and curriculum affected preparation, which impacted lesson facilitation and student achievement. I noticed that participants had mixed feelings about the school science curriculum, FOSS, as they explained that its preparation requirements were extremely time consuming, even if they liked some of its activities. Peyton from the 5th grade team at Baya Elemenatry School informed me at the beginning of the year that:

> "It takes a lot of time to go through the [FOSS] kits, find what you need and then set it up. And then a lot of times stuff doesn't fit back into the kits the way it came out, so you have to store it somewhere else. It's a lot of going through boxes" (Peyton, Pre-Interview, September 27th, 2018).

She discussed how preparation was not the only time-consuming aspect of FOSS. Peyton and multiple other teachers shared that not every activity in the curriculum was relevant to their district's science standards. One of the 4th grade teachers from the same school explained:

> "Not all of the [FOSS] investigations in there align with a standard that has to be taught, so there's more investigations than what there have to be...It actually takes a lot of time to go through and figure out which investigations you want to do each week. And then, the boxes are not organized in a way that really makes sense" (Farrah, Post-Interview, May 23rd, 2019).

One of the educators who was not fond of FOSS was Samantha in the "Seasoned Squad" group. During our final interview, I asked her how she normally uses the FOSS curriculum and what her perspective was on its lessons. She said:

> "Usually, [I] read it beforehand. But for some of them [the lessons], I would have to have it open while I was teaching like reading out of it or looking back to it. And then I just feel like I don't know what I'm talking about because I'm trying to do it in the right order so it will work and that's not real science either. Because I feel like real science is actually experimenting and trying and not just following the prescribed steps" (Samantha, Post-Interview, May 28th, 2019).

Samantha was not alone in her beliefs on FOSS. Emma and Callie from the "Newcomers," and Michelle from the "One Woman Show" at Anara Elementary School had similar views on the procedure that FOSS provides:

> "It's [FOSS] very scripted. It's, 'This is exactly what you're going to do, and exactly what you're going to find.' Even when they [FOSS] do an anchoring event, they immediately

want you to tell them [students] why it happened and what's going on, which is frustrating to me, so I usually don't do that" (Emma, Post-Interview, May 13th, 2019).

"I really wish we didn't have FOSS. I wish we could come up with a curriculum that's not kind of dry and planned out for them. You know, it [AST] allows them to come up with their own experiments and stuff" (Callie, Post-Interview, May 17th, 2019).

"Because it [FOSS] is so scripted, it doesn't really leave time for, not exploration, but just asking them questions. All of that has to come from me. Like, 'Oh, this would be a good time to ask this question, this would be a good time to ask this question.' It doesn't just come out and say, 'Why do you think this is going on?'" (Michelle, Post-Interview, June 3rd, 2019).

During the final interviews, I asked participants to compare their current FOSS curriculum to the AST framework. I was curious to see if they believed AST was usable in the formal elementary education setting since the framework originally focused on secondary science education (Windschitl, Thompson, & Braaten, 2018). I was unable to find empirical research on AST in elementary classrooms, so I had teachers share what, if anything, they found practical and advantageous about the AST framework. Emma believed that AST is very practical in the elementary setting, and she stated, "It felt much more manageable [with AST]...I just felt like I had a stronger understanding of the curriculum content and pace" (Emma, Post-Interview, May 13th, 2019). Like Emma, other participants expressed that they felt AST was more manageable and actually easier to use than FOSS. They found most of the AST practices to be practical in the formal elementary classroom. When I asked which AST practices they believed most advantageous, participants most frequently discussed liking to use the anchoring event focused on a specific phenomenon, having students continuously revise models, asking open-ended questions, and implementing the “Gotta Have Checklist.” One practice some participants believed was more difficult to implement was the “Summary of Activities” chart where they keep a running record with students on what knowledge was gained during each activity. Many teachers discussed that the lack of time provided for science affected their abilities to summarize the activities with students.

Practices – Shifting to Student-centered Approaches

Another question I asked during the final interviews was how the participants’ perceived the PHP-PLC affecting their science teaching practices. Samantha revealed to me during our final interview, “I think it was a lot more less direct instruction...I do think it resulted in more student learning doing stuff like this. And then definitely the PLC helped us plan a lot better than normal...This is like the best planned science unit that we've ever had in the past five years” (Samantha, Post-Interview, May 28th, 2019). Many participants related to Samantha’s experience with the PHP-PLC in that they felt it benefited their science teaching planning and practices. A common theme in participants’ responses was that they improved upon allowing students opportunities to explore, investigate, and ask questions during science. Some teachers even noted an improvement in student learning. Farrah mentioned at the end of the year:

> “Something I find with science normally is that kids will remember doing an experiment, but they don't remember the purpose of it or what they learned during it. It was just [students saying], "Oh, I remember that one time when we looked at this." [Teacher responding], "Oh really? What did you learn during that?" [Student replying], "I don't know, we just saw this." But, I feel like they learned a lot during that time [AST unit

> implementation], and they are able to talk about the things that they learned" (Farrah, Post-Interview, May 23rd, 2019).

Farrah continued on about how the PHP-PLC affected her science teaching practices and shared how she noticed herself focusing more on student explanations and wonderment rather than immediately providing them with the correct answers. She also discussed how her PHP-PLC experience transferred to her teaching practices in other subject areas, specifically math. She explained:

> "It's like they [students] know I'm not going to give them the answer. And a lot of that I feel like has come from the Ambitious Science Teaching, too. Because to be honest, a lot of times, I don't know the answer. And I've noticed that when I'm like, 'Oh, I don't know, what do you think about that?' It pushes them to keep working instead of saying, 'Yes, this is right.' And then they sit there, and they're done kind of thing. So, I feel like that's rolled over into some other subjects" (Farrah, Post-Interview, May 23rd, 2019).

However, not all participants' science teaching practices were positively impacted by the PHP-PLC. As I describe in the vignettes, Danielle utilized traditional methods throughout the school year. She was not the only participant whose practices continued to be teacher-centered. Michelle from the "One Woman Show" PHP-PLC team at Anara Elementary School discussed with me at the end of the PHP-PLC how she continued to struggle with letting go of control during the lessons. She informed me that this had been a struggle for her entire eight years of teaching, and it was an area she still strove to work upon. She commented:

> "I would definitely say that I'm the kind of teacher that, in all areas, I feel like I over-scaffold a lot...Very rarely do I ever say, 'Here's your stuff. Go.' It's usually, 'Okay, this is what we're doing.' And I show them how to do it...I wish I could be more of that kind

> of teacher, but then nine times out of ten it causes, 'I don't know what I'm doing!'...When they're doing something that's hands-on, I want them to do it right. And so, I feel like I have to either do it for them or literally show them" (Michelle, Post-Interview, June 3rd, 2019).

Even though teacher practices varied, the pre- to post-SIPS survey responses indicated that traditional instruction decreased, while student-centered instruction increased. The three items that increased the most were science lessons allowing for students to "choose variables to investigate," "generate questions or predictions to explore," and "identify questions from observations of phenomena." A majority of participants found AST to have beneficial practices that they wanted to continue incorporating in their science instruction. Many felt that focusing the unit lessons around an anchoring phenomena and essential question were effective strategies for supporting students' learning because they were able to more readily connect important science ideas together.

Overall, participants of the PHP-PLC seemed to be positively impacted by the intervention. Each PHP-PLC group had their own dynamics and context played an important role on their experiences. Many teachers had an increased science teaching self-efficacy and ended the year with positive beliefs about science education. After incorporating a science unit using the AST framework, teachers indicated that they felt well prepared and that students benefited from it. They included more student-centered practices and found participating in the PHP-PLC to be advantageous to their science instruction. Prior to their participating with the PHP-PLC, teachers held negative feelings about their schools' adopted curriculum: FOSS. They found it to be time-consuming, too procedural, and a hassle to setup the materials. Samantha stated at the beginning of the year: "I feel like when we plan the activities ourselves, I don't necessarily use the ones from the [FOSS] kits, we get a lot more done. It's a lot easier to plan. I feel like they go more smoothly. We get more excited about them" (Samantha, Pre-Interview, October 5th, 2018). Multiple PHP-PLC teams shared that they were going to use AST in their classrooms in future years and work toward gradually altering/creating more AST-based units.

Contrastive Case Studies of Tier 2 Participants' Experiences

While the Tier 1 data and findings provide insight on the overall experience and effects of the PHP-PLC on participants' science teaching identities, I utilized two contrasting cases of Tier 2 participants to offer a deeper understanding of the experiential influences that shaped the overarching patterns. In choosing case study participants, I relied on multiple deciding factors, which I provide a rationale for in the methods section: (1) highly ambitious to improve science teaching practices, (2) highly motivated to participate in the PHP-PLC, (3) member of a highly motivated and enthusiastic PHP-PLC team, and (4) having a unique professional background compared to other participants. The two teachers chosen as cases differ in their school contexts, grade levels, teaching experiences, and data outcomes. The first Tier 2 participant, Brandi, was part of the fourth-grade team at Baya Elementary School, had two previous years of teaching experience, and had a tremendous increase in her science teaching self-efficacy. In contrast to Brandi is Holly, a fifth-grade teacher at Anara Elementary School who has had eighteen years of prior teaching experience and decreased in her science teaching self-efficacy.

I begin each case study by describing their professional background and context, which includes brief summaries of their participating colleagues' experiences to offer an understanding of the PHP-PLC dynamics and the influence of individuals on each other as a team. Although all the teachers had differing results, it became clear that their individual identities were connected to the complex contexts within the PHP-PLC teams. The effects of the PHP-PLC on the educators' science teaching identities depended upon many interconnected factors, which I describe throughout the rest of this chapter. Since I analyzed the data through a constructivist, interpretivist lens, the following findings are to be understood as my own sense-making of the participants' experiences with the PHP-PLC through the investigations of their interviews, surveys, and reflections, as well as my observations and field notes.

Case Study 1: Brandi – Let's Find Out Together

Context – Surrounded with Knowledge, Positivity, and Support

At the beginning of the 2018-2019 school year, Brandi was starting her third year of teaching elementary students. The Midwestern state's teacher licensure program requires two full years of administration-approved teaching in order for educators to transition from an initial license to a standard license that is valid for five years. Brandi had successfully earned her standard license and was working toward maintaining it by continuing her professional learning. She was enrolled in online graduate courses at a local private university, some of which were focused on STEM pedagogies. During our initial interview, Brandi mentioned that these courses emphasized the importance of using open-ended questions and allowing the students to explore rather than using the traditional scientific method approach (Brandi, Pre-Interview, October 5th, 2018). She expressed her eagerness to participate in the PHP-PLC and began the year feeling comfortable about learning with the students, which some teachers find challenging. Brandi said, "When kids ask me questions that I don't know, I just have to tell them, 'Let's find out together'" (Brandi, Pre-Interview, October 5th, 2018).

Brandi was the youngest educator of Baya Elementary School's 4th grade teaching team. Six other teachers – three general education and three English as a Second Language (ESL) – accompanied her in the PHP-PLC meetings, making up the largest and most experienced group. Both PHP-PLC teams at Baya Elementary School were unique in that they started the year off with a new co-teaching initiative. The school leaders believed that English Language Learners

(ELLs) would greatly benefit if they had additional support during vocabulary-dense instruction, so the ESL educators were assigned specific classrooms to assist with teaching both science and social studies (Diana, Pre-Interview, September 24th, 2018). A majority of the PHP-PLC participants voiced excitement for this new initiative, including Brandi. She explained, “I think it's really great that we have ELL supporting us at that time...because I think a lot of my ELL students really exceed well in science, but for them to have that support and that second teacher in the room really helps them. It's the one subject that a lot of students feel they're pretty proud of themselves in. I just want that to continue” (Brandi, Pre-Interview, October 5th, 2018).

Unfortunately, the ESL educators’ schedules were changed mid-year, and they were unable to continue co-teaching. Despite this, they participated in the PHP-PLC till the end and provided input on how to best support ELL students. With their guidance and the other more-experienced teachers’ support, Brandi was surrounded by knowledgeable peers. Although I was initially uncertain on how seven voices would impact the dynamic of the PHP-PLC meetings, they were the most on-task and efficient group. They also had a collective positive outlook on both their students and the PHP-PLC itself. Farrah, the most experienced teacher of the 4th grade general education team, stated in our initial interview, “I'm excited about the ambitious science that you're showing us...I think it's going to be really great and I think it's going to be a success...We have some really, really bright kids that do question a lot of different things. And maybe some of the kids who aren't quite there yet will find it to be interesting, will engage a little bit more in science and want to participate more...We're excited about this, and I'm glad that you came to us about this and have let us be a part of this with you” (Farrah, Pre-Interview, October 5th, 2018). Brandi was part of a highly motivated and enthusiastic team that I named, “Seasoned Squad.”

Self-Efficacy – Unlocking Beliefs in Capabilities

Even though Brandi had taken a few graduate STEM courses and felt comfortable learning with her students, she mentioned how the science content was not her strong suit. She said, “I actually very much love teaching science, but the only thing that scares me is a lot of the times I don't know a lot about the science either, so it's like a learning process” (Brandi, Pre-Interview, October 5th, 2018). According to her responses on the initial STEBI survey, she scored well below average compared to the other participants. She agreed with the statements, “When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better,” and “I find it difficult to explain to students why science experiments work” (Brandi, Pre-STEBI Survey, November 15th, 2018). Both of these prompts are related to Brandi’s personal science teaching efficacy (PSTE), which has been found to be a more reliable prediction of a teacher’s practices (Lakshmanan, et al., 2011).

In response to Brandi and other teachers’ concerns about science knowledge and ability to answer student questions, we agreed to spend time on understanding the science content as we were planning the units during our PHP-PLC meetings. We also had a couple of content-expert guests attend our meetings and lesson implementations throughout the school year. For the first unit – for which we only had time to prepare half of the activities – the content was focused on geology. I invited Luca, a PHP undergraduate employee who was majoring in geology at Midwestern University, to join one of our meetings to answer any questions the teachers had. He offered explanations on earthquakes and fault lines, as well as suggestions for activity ideas (Meeting Notes, November 6th, 2018). For our completed final unit at the end of the year, a portion of the content was related to mosquito biology. The PHP program coordinator, Nora, had earned her doctoral degree in entomology, making her an expert in mosquito science. She joined a couple of our PHP-PLC meetings, as well as provided support during the mosquito-related lessons.

Additional support may have played a role in Brandi's experience with the PHP-PLC. Brandi started the year with a comparatively low PSTE, but she ended up with the largest increase in her STEBI self-efficacy score. Her reaction to the two STEBI statements mentioned above had completely changed after the PHP-PLC intervention. Brandi's self-efficacy increase was substantially greater compared to the other participants, and she shared with me during our final interview:

> "Even at the beginning of the year, I totally remember being like, 'I have no idea how to teach science, I don't know how to answer the questions.' Even though now I feel like I've learned a little bit more on the [standard] scales and information about science...it's more of how to handle teaching science and how to explore with the kids because even though I still might not know the answers, it's not like I just say, 'Oh, I don't know,' and then we don't ever think about it. It's like, okay, let's go explore it" (Brandi, Post-Interview, May 22, 2019).

Beliefs – Students Need Exploration

Brandi expressed to me during our initial interview that she preferred to see herself as a facilitator/interpreter during science instruction. However, the curriculum Baya Elementary School adopted, FOSS, had a contradicting role for educators. Brandi discussed that a typical science lesson from the current school curriculum is a step-by-step process that is not effective in enhancing students' knowledge. She believed that, in the end, students were not "really learning and discovering it, and it doesn't stick in their brain, so [to her] the process of getting it all ready is very time consuming and not worth it just because of their end result of learning" (Brandi, Pre-Interview, October 5th, 2018). Brandi wrote in the mid-survey:

"I want my students to be curious learners. I want them to feel comfortable asking questions and feeling confident trying to find the answer through experimenting and researching. I want them to all believe they can be a scientist and test their predictions and make observations" (Brandi, Mid-Survey, January 10th, 2019).

Considering the school curriculum was not providing instruction that would meet her goals, she resorted to exerting efforts toward finding outside sources to plan for science, which required her to use personal time and money. One of her dislikes about science was the amount of preparation the school's curriculum demanded, similar to what a majority of the other participating teachers had expressed. During her final interview at the end of the school year, Brandi explained:

"I'm always thinking about the more you prep the better it hopefully will turn out. It was very true. Everything we had was ready to go. We didn't have to take time in the middle of the day. There was less student behavior issues during that time because I was so prepared. Usually with other science things, if I'm reading it from a FOSS kit, I have to read the directions. But we already knew what we were going to do, and how we're going to teach it. The students were really engaged" (Brandi, Post-Interview, May 22nd, 2019).

Brandi elaborated on how she has felt this year was less discouraging for science teaching because the PHP-PLC provided time and funds to plan and prepare. She said: "I think it was a really good experience and super beneficial to all of the teachers. I really like to be able to have that time to PLC with everyone because we never have time for science in our planning" (Brandi, Post-interview, May 22nd, 2019).

Practices – Science is an Everyday Thing

Another goal Brandi set was to incorporate more science instruction into her classroom. She stated: "I really want to try to get it [science] in there, whether it's like morning work of observations of a picture, or where they have a question and they find out the answer and stuff in a science way" (Brandi, Pre-Interview, October 5th, 2018). Per our final interview, she discussed this goal with me and said, "I've been doing science still even though we're done with it because kids really love it...Science could be anytime during the day. It's not just in the afternoon during my science time" (Brandi, Post-Interview, May 22, 2019).

According to Brandi's pre- and post-SIPS survey responses, she decreased in implementing traditional science instruction methods from the beginning to the end of the school year (Brandi, Pre-SIPS Survey, January 1, 2019; Post-SIPS Survey, May 16th, 2019). She explained, "I think definitely what changed is more student-centered, more driven by the students, having those discussions" (Brandi, Post-Interview, May 22, 2019). When comparing my lesson observations, I noticed this to be true in that there was much more student-talk during Brandi's end-of-the-year science lessons (Observation, May 16th, 2019). Brandi recorded one of these lessons and reflected:

> "I always enjoy watching myself on the video because I can see what's going on with the students. I feel like I, as a teacher though, have days where I'm off or I'm not feeling it and whatnot. When I watch it, usually on all my videos I do a really good job because I know I'm getting recorded, and so, I like knowing that I am a good teacher even though I have my bad days" (Brandi, Post-Interview, May 22, 2019).

After participating in the PHP-PLC, Brandi kept her "let's explore together" beliefs while increasing her science teaching self-efficacy and having the time and resources to achieve her goals.

Case Study 1: Holly – Afraid to Spill the Beans

Context – Experienced but Unaccustomed

When comparing and contrasting participants' contexts to Brandi's, no one was quite as polar opposite than Holly. I provide the following exchange I had with her as an example:

> Holly: "I always spill the beans. I always, always spill the beans. I need to learn just to be like, 'What do you think? Why? And let's figure it out, and let's talk.' Because I don't give them enough of a chance sometimes to try and suss out for themselves what actually is going on."
>
> Me: "Why do you think that is?"
>
> Holly: "Crap teacher, I don't know. Maybe not having faith that they'll figure it out. Like, it's okay every once in a while, if they're not getting it, to feed them stuff. But I just as a whole, I need to do better" (Holly, Post-Interview, May 13th, 2019).

With eighteen years of teaching under her belt, she had the most general education classroom experience out of all the participants. As reflected in the brief conversation above, however, Holly did not have a very positive view on her science teaching abilities. Holly was part of the "Newcomers" group at Anara Elementary School, which I named because all three of the 5th grade educators were new to the district. However, Holly was no newcomer to the teaching field. Whether it was her experiences or personality, she often led our PHP-PLC meetings and kept us on track. Holly was interesting to me as a case because she began with an above average pre-STEBI self-efficacy score, but slightly decreased by the end (Holly, Pre-STEBI Survey, November 12th, 2018; Post-STEBI Survey, April 29th, 2019).

The other members of Holly's team, Emma and Callie, had seemingly more positive outcomes. During our last PHP-PLC meeting, we discussed their experiences with the intervention as a group, and I noted in my reflection, "They said that it was challenging because they were all new to the school district this year, so not only were they having to learn all the curriculum and how the school works, but this also just added to that" (Meeting Notes, April 29th, 2019). It appeared that their context put a hindrance on their experiences with the PHP-PLC. However, they expressed how they believed it positively influenced their science teaching. Each participant in the "Newcomer" group shared that they would want to continue the PHP-PLC into the next school year if possible.

Self-Efficacy – Improving Knowledge Creates a Sense of Self-Doubt

Although Holly, like her teammates, expressed having a positive experience with the PHP-PLC, her self-efficacy scores did not align. During our final interview, we looked at her pre- and post-STEBI scores and discussed her beliefs on the outcomes. Holly's had five instances on the survey where she went from a positive response to an uncertain one. It became clear that Holly doubted her abilities to a greater degree after participating in the PHP-PLC. She reflected:

> "I feel like even though I should feel better about my teaching in science, it's not that I don't, it's just I think I'm more aware...Now, I'm like, 'Oh, crap. I'm really not doing that right.' Whereas, I don't know that I really felt that way before we started doing it [the PHP-PLC]. Just maybe a little more aware of what I should be doing and what I could be doing better" (Holly, Post-Interview, May 13th, 2019).

There were multiple instances throughout our final interview where Holly displayed self-doubt. When I asked her what she thought would be beneficial to change in the PHP-PLC if we did it again, she described possibly changing the phenomenon the unit was focused around. Then, she started to have doubt in herself and thought it was also highly likely that it was her own misconceptions and that she didn't totally understand the content.

Holly had the lowest self-rated understanding of AST components during the middle of the school year. I asked teachers how familiar they were with different AST practices using a Likert scale ranging from not familiar at all to slightly, moderately, very, and extremely familiar. Holly often responded with “slightly familiar” and “moderately familiar,” and never “very” or “extremely” familiar (Holly, Mid-Survey, February 2nd, 2019). She explained in her final interview, “I think I need to go back and reread, and do more of the reading again. I think it [the PHP-PLC] was a good introduction, but I could not turn around and teach someone about it [AST]...I don't feel comfortable enough to do that. I think I have more learning to do as far as that goes” (Holly, Post-Interview, May 13th, 2019). Similar to my claim from Tier 1 data, it appears that content and pedagogical knowledge play a huge role in teacher self-efficacy beliefs as Holly demonstrated. While the PHP-PLC positively influenced the self-efficacy of novice teacher Brandi, it seemed to be more of an eye-opening experience for Holly that negatively impacted beliefs about her personal science teaching capabilities.

Beliefs – Challenged by Student Misconceptions

Similar to Brandi and other participants, Holly expressed concern about the school curriculum, FOSS, and how it required an excessive amount of preparation. She called it a “necessary evil” during our initial interview (Holly, Pre-Interview, September 22nd, 2018) and discussed prepping at the end of the year by saying:

> “It was almost easier with AST because we just had to go get it [the materials] than with the FOSS, where you know it's there, you just don't know where. You have to dig it out and it's all up high [located on top of tall cabinets]. I like the prepping for this and the planning for it, because I really felt better while doing it. Even though I didn't do everything right and I dropped the ball on things, I still feel like I was better prepared for this than I would be for some other things. Because even though you read it, then when

you get in there to do it, you don't want to spend the whole time reading out of the book for what to do. I didn't feel like I did that as much with our unit. I was better able to teach it, knowing what to do" (Holly, Post-Interview, May 13th, 2019).

Holly believed that the students gained science knowledge and were more open-minded during her AST science unit implementation. Across multiple data responses, Holly emphasized her belief in the importance of hands-on instruction to best support student learning. However, she believed an obstacle that affected her science teaching possibilities was a "lack of background knowledge and student misconceptions" (Holly, Reflection, April 29th, 2019). She discussed with me that the specific content they were learning was quite new to them, which made it challenging for her to practice AST in the way we planned. She revealed that this challenge decreased the amount of time for the instruction we prepared. Holly was able to implement some AST practices, like keeping a continuous public record of learning, due to the challenges she faced.

Practices – Discouraged but Not Defeated

During my final observation of Holly's science instruction, I noticed that her report about students' background knowledge was true. We did not plan accordingly to meet the students' academic needs as some of our activities required prior exposure that we did failed to prepare for (Observation, April 2nd, 2019). However, even though Holly was not able to successfully implement all of the AST practices, she did indicate that the students were more engaged during the unit. She felt like she incorporated more open-ended questions and hands-on tasks. In our final conversations, Holly explained, "What really was awesome was that they weren't doing all of this science reading. They were talking, discussing, viewing. They weren't just reading about everything" (Holly, Post-Interview, May 13th, 2019). Holly's pre- and post-SIPS survey indicated that she decreased in implementing traditional science instruction methods from the beginning to the end of the school year (Holly, Pre-SIPS Survey, December 10th, 2018; Post-SIPS, April 29th, 2019).

Although Holly felt discouraged by not being able to incorporate all of the AST practices, she did discuss future goals with me during her final interview. With regards to finding it difficult to keep a continuous public record of student learning, Holly thought a solution may be to put a student in charge of updating it after each lesson. Another goal she set was to "become more familiar with the standards and build a repertoire of activities for students to do" (Holly, Post-Interview, May 13th, 2019). Holly was nervous throughout the year about "spilling the beans" and not allowing students to figure things out on their own, but she still felt that after participating in the PHP-PLC, she had a better understanding of reform-based science teaching methods. She may have felt somewhat discouraged, but not defeated. Her motivation remained high, and she wanted to continue putting efforts toward learning and implementing AST practices.

Both case study participants indicated that the PHP-PLC was a positive experience for them. They ended the school year with positive beliefs about science education, but their context and science teaching identities were significantly different. Holly had sixteen more years of teaching experience than Brandi, but Holly was new to her context. Both participants were part of a highly motivated team, but Brandi's peers were more experienced. Brandi had the largest increase in her science teaching self-efficacy score, while Holly's slightly decreased. Holly reported feeling constrained by her students' misconceptions and found it challenging to incorporate all of the AST components into her practices. She also had the lowest self-reported understanding of AST compared to the other participants. Although Brandi and Holly had different experiences, they were determined to continue improving their science teaching practices and aimed to incorporate AST into their classrooms during the next school year.

CHAPTER 5. DISCUSSION

"It's a nightmare in here," Danielle exclaimed during our final interview (Danielle, Post-Interview, May 21st, 2019). Although she began the year full of excitement for science education and spoke fondly of her PHP-PLC experience, many other factors influenced her post-intervention perspective. At the end of our final interview (May 21st, 2019), we had the following conversation:

> *Me: "You said that you didn't do as much as you wanted this year...I don't want to just make assumptions of why, so if you were to tell me reasons you feel like you didn't meet those goals, what do you think those might be?"*
>
> *Danielle: "I think, honestly, I've just been very defeated with this group, and I haven't wanted to put the effort in...I think I'm just very burnt out...This year very much made me question the profession, whether I want to do it or not. I dread getting out of the bed in the morning."*

Danielle transitioned from focusing on the classroom and students as the center of her negative experiences to discussing how her personal life had truly played a huge role. She stated, "I mean, there's just a lot going on right now. I just don't have the energy to put in, and that's not on them [the students]. That's on me" (Danielle, Post-Interview, May 21st, 2019). While Danielle ultimately determined she wanted to give teaching one more shot, she relocated to a rural school.

As a second-year teacher, Danielle did not feel equipped to step outside her comfort zone and adopt a new science pedagogical framework. Danielle is not alone in this as previous research has shown how many educators teaching in highly diverse, socioeconomically-stressed urban schools are ill-prepared to do so effectively (Aragon, et al., 2014; Moore, 2008b). In addition, teachers with a low self-efficacy are more likely to utilize insufficient pedagogical methods (Bandura, 1977; Bandura, 1989; Dembo & Gibson, 1985; King, Shumow & Lietz, 2001). The inadequate preparation of these teachers is a key factor of the inequitable education opportunities of marginalized student populations, and the research literature has proven that high-quality professional development opportunities focused on reform-based efforts positively impact teachers' practices and student achievement outcomes in science (Lakshmanan, Heath, Perlmutter, & Elder, 2011; Lee, Hart, Cuevas, & Enders, 2004; Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013). The purpose of the PHP-PLC professional development intervention was to address the problem of inadequate educator preparation, specifically for those who teach at highly diverse, socioeconomically-stressed urban elementary schools.

In this chapter, I discuss what I think the findings I describe in Chapter 4 mean for science education by providing a summary of participants' experiences, recommendations for practice, and suggestions for future research.

Summary of Findings

As demonstrated by the two case study participants, Brandi and Holly, years of experience is not a reliable indicator of an educator's science teaching self-efficacy, beliefs, and practices. The beginning and ending PHP-PLC data differed greatly between these two. After participating in the PHP-PLC, Brandi – a novice teacher at Baya Elementary School – had an increased science teaching self-efficacy, positive beliefs about science education, and improvement in her science instruction. She was surrounded by experienced, highly motivated peers, and finished the year with enthusiasm to continue incorporating AST into her teaching methods. Holly had a similar devotion to advancing her science practices using AST, but her self-efficacy outcomes were not the same. Although Holly was the most experienced general education teacher of all the participants, her context, science teaching identity, and experiences with the PHP-PLC negatively impacted her science teaching self-efficacy. She explained that learning about reform-based science practices opened her eyes to what she was and was not achieving, which made her feel less confident in her own abilities. However, she wanted to continue learning and improving upon her teaching. Overall, the participants of the PHP-PLC increased their science teaching self-efficacy, ended with positive beliefs about science education, and incorporated more student-centered, reform-based practices.

A major finding from this study was how the participants viewed AST as more manageable compared to their schools' adopted curriculum, FOSS. Teachers expressed that FOSS was time-consuming to prepare for. They were specifically critical of the FOSS kit setup and believed it to be a hassle. Some were so discouraged by this that they said it was not always worth their time using FOSS because preparation would take too long for even short activities. Teachers also felt deterred by how FOSS is scripted. It created stress around ensuring that they were implementing the lessons properly and not missing any steps. In addition, some participants believed that the pedagogical methods of FOSS were cookbook-like and too procedural to allow students to explore on their own and ask their own questions. After learning about and using the AST framework in their classroom, these beliefs about FOSS grew stronger. Although participants indicated that they needed to learn more about AST in order to feel completely confident in implementing all of the practices, they found AST to be easier to use than FOSS and aimed to utilize it in upcoming school years. This finding is significant because it counters the intent and claim of FOSS to support teacher preparation for and improve implementation of their science teaching.

Recommendations for Practice

My recommendations are based on participants' suggestions and experiences, as well as my own perceptions as a member of this study, while all being informed by the research literature. In reference to the three themes of my literature review – science education, science teacher identity, and teacher professional development – I present my recommendations for multiple impact levels, including macro, meso, and micro influencers. These levels include policy, teacher preparation, and practice suggestions. Since the intended impact of this work – and the supporting broader project – was to improve science education outcomes for historically-excluded youth, I shift the context of my themes to focus on equity using a social justice lens. I believe these recommendations align with interrupting the reproduction of science educational disparities. After facilitating the PHP-PLC and completing my analysis, I propose the following ideas for the three themes of my research.

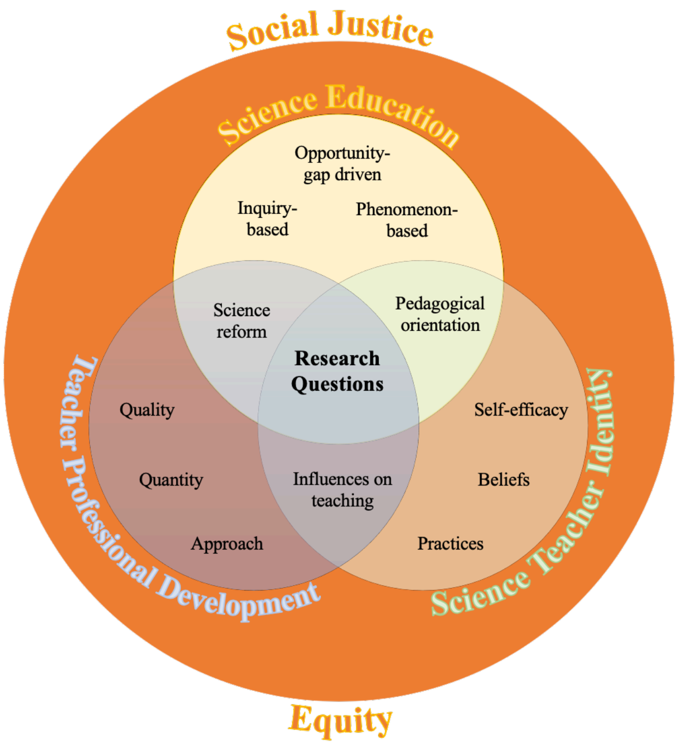

Figure 5.1 Three themes of my research with social justice context

Teacher Professional Development – Time and Positive Support

Based on what I have learned from implementing the PHP-PLC and feedback I received from participants, I have four recommendations for future PLC science education facilitators. It should be noted that some of my suggestions are influenced by my own perceptions as a participant of this experience.

Explicit Experiences

I asked each participant what they liked and what they would change about the intervention. During my final meeting with the "Newcomers" group at Anara Elementary School, I wrote down notes on the ideas they discussed as a team:

> "They think that it would be beneficial to have one to two days of workshops where all we do is dive into Ambitious Science Teaching with both video and lesson plan examples. They really liked the idea of keeping the meetings to be every other week after school. They said that they wanted just a little bit more time to solidify that unit plan and possibly have the chance to go back through it and look at the AST practices in order to see what they could change so it would best fit the framework" (Meeting Notes, April 29th, 2019).

Other teams also mentioned how they would have liked to have more explicit modeling of AST. Some participants offered the idea of incorporating more video examples of AST lesson plans in action. Therefore, I would recommend for future PLC facilitators to provide participants with plenty of opportunities to have experiences that explicitly demonstrate the implementation of the desired practices. Providing this additional support, or scaffolding, is supported in the literature. Highly-scaffolded professional development groups had higher success rates for both teacher self-efficacy and student achievement compared to professional development groups who used self-study (Kleickmann, et al., 2016).

PLC Work Time

Another suggestion I have is to provide PLC members work time during the meetings. More often than not, when groups would set goals for completing tasks at home, they were unable to accomplish them before the meetings. Teachers have busy enough schedules and would benefit greatly from using meetings for independent study/work time. Since teachers' time is limited, it is valuable and should be treated as such. Teachers need extra funding to pay for "outside of school" planning and prepping to feel encouraged to plan more effective lessons. As Brandi stated in her final interview, "It's hard when, to be a successful teacher, I feel like you have to go way outside your paid hours" (Brandi, Post-Interview, May 22nd, 2019). She believed that the extra planning and prepping time was spent on the elevated subjects – reading and math – so science has often been the topic that teachers may feel less obligated to work on outside of school hours. Brandi expressed that the stipend offered by the PHP-PLC allowed for her to feel that she was being paid to do her job, which is only right. As motivation has been found to be a key factor in successful professional development interventions (Kennedy, 2016), being provided time and funding may contribute to increased motivation.

Longer PLC Meeting Times

The PHP-PLC meetings averaged to be one hour every other week immediately after school was dismissed throughout the year. This was the agreed upon schedule each team had at the beginning of our planning. However, the teachers and I had noticed that an hour was not sufficient for optimal productivity. There were a few instances where a couple of the teams had to reschedule hours that we would simply add to a future meeting. These two-hour meetings seemed to be more effective since we could keep the ball rolling as we would normally come to an abrupt halt on our planning during one-hour meetings. It normally took some time at the beginning of each PHP-PLC meeting to reflect on where we left of during the previous session, so the two-hour meetings alleviated some of this. As one participant explained in her final interview: "The thing that's hard is when you have an hour, you dive into it and then you don't meet for two weeks and then you have to re-hatch everything, so I like bigger chunks of time" (Kourtney, Post-Interview, May 20th, 2019). The "Newcomers" experienced both one- and two-hour sessions, and the latter was one of our most efficient and productive meetings.

Science Education – AST in the Elementary Setting

As for my suggestions on science teaching practices, I recommend that elementary schools and science professional development interventions adopt the AST framework. Since I was unable to locate any extensive research on AST in formal elementary settings, the finding from my research that elementary teachers perceive AST as potentially easier to implement than FOSS is a valuable contribution to the current science education literature.

Phenomenon-Based Approach

While inquiry-based science teaching practices have been found to be successful in some studies and is popular among reform-education practices (Capps & Crawford, 2013; Geier, et al., 2008), AST incorporates these strategies, but extends them. AST focuses on connecting multiple science ideas through a phenomenon that occurs in the natural world in order to encourage students to find the relationships between the different science concepts (Windschitl, Thompson, & Braaten, 2018). All of the participants found it to be beneficial to their science teaching and student learning. They were fond of the phenomenon-based approach where they focused the entire science units around a specific, real-life event (a.k.a. the anchoring event). Some participants mentioned how this allowed for students to make better connections throughout the unit activities. Along with the anchoring event, teachers emphasized the following AST practices as being advantageous to students' science learning: focusing the unit on an essential question, asking open-ended questions, having students create revisable models, and utilizing the "Gotta Have Checklist." Some participants did express that one AST practices that was challenging to implement was revisiting a "Summary of Activities" chart after each lesson because they would often run out of time. As noted above, a majority of the educators felt like they needed more time and practice with the AST framework before they would be fully confident to expertly incorporate it in their science teaching methods.

Time, Time, and More Time

One of the most prominent concerns participants had for science education was the lack of time. The teachers explained that due to policies and administration decisions, English language arts and math are more heavily pushed subjects, leaving little room for science or social studies. As Blank (2013) determined in his comparison of NAEP achievement scores as connected to the amount of instructional time, classrooms with an average of four hours of science instruction per week received significantly higher scores than those with the lowest amount of instructional time, which was around one hour per week (Blank, 2013). The teachers in this study indicated that they have around two hours per week to teach science for half of the school year as science and social studies rotate with one another. Participants often stated that they wished they had more time to not only teach science, but also for planning and preparing purposes. Considering their responses and the low science achievement scores at these schools, I recommend policy makers and administration make science education a priority; especially in underserved, socioeconomically-stressed urban schools. Almost all of the teachers in this study expressed their love and the students' love for science, and they find the current climate of science education unfortunate.

Teacher Identity – Professionalize the Professionals

The PHP-PLC focused on improving three interrelated components of science teacher identities: self-efficacy, beliefs, and practices. It is clear from my findings that years of teaching do not necessarily correlate with effective science practices. Instead, their prior experiences with reform-based pedagogies, the context in which they teach, and the school curriculum appeared to be much more influential. I recommend that beyond providing teachers with in-depth and reform-based science professional development opportunities, districts need to attend to the culture and science curriculum in their schools.

Scrap the Script

"I feel like if I could be a free spirit science teacher, I would like it more" (Michelle, Pre-Interview, September 21st, 2018). A major finding from my study was how teachers found AST – a completely new framework to them – easier to implement than their schools' familiar curriculum: FOSS. Teachers' perceptions of FOSS's kit-based and scripted curriculum was quite unexpected considering how the research literature finds it favorable (Clementson, 1991; Full Option Science System, 2020). Contrary to literature, the participants believed it to be too time-consuming, too procedural, and too constraining. They enjoyed and preferred the AST framework as it provided them and their students ownership of science learning. Rather than assuming teachers need everything laid out for them in a step-by-step curriculum, I recommend that districts allow creative freedom to respect and respond to the professionalism of teachers.

Relationship Building

Another essential factor to science teacher identity development is context, which includes the peers that teachers collaborate with. Efficiency and productivity during PHP-PLC meetings seemed to also be influenced by the dynamics of each team. I noticed that a couple of the groups had stronger and more positive relationships with one another than other groups did. Teachers with the positive relationships appeared to be more comfortable with sharing out ideas and opinions, which added richness and depth to the PHP-PLC meetings. Personally, I had varying levels of connections with the teams, some more than others, and I felt more confident and effective with those I built stronger relationship with. From my experiences, I recommend emphasizing relationship-building for teacher teams in order to encourage more positive and productive collaborations. I believe people are more motivated and dedicated in putting forth their best effort when they are surrounded by a positive and supportive team. Considering my methodology was more focused on individual participants' experiences, I explain in the next section how this is a topic that needs more attention in the research field.

Suggestions for Future Research

Before implementing the PHP-PLC, I had the misconception that years of experience was going to be a strong indicator of participants' beginning and ending results. Since I was proven wrong during the study, I became quite curious about what factors were influencing educators' science teaching self-efficacy, beliefs, and practices, outside of the PHP-PLC intervention. This motivated me to ask my second research question, which I continue to be intrigued by. If I were to do this study again, I would set it up to focus more on participants' contextual elements because I noticed an apparent difference between the outcomes of those who were at Anara Elementary School and those at Baya Elementary School – schools located only one mile apart from the other. The participants at Baya Elementary School reported using less traditional science teaching practices and had a more significant decrease in using traditional practices. Baya Elementary School participants also had more student-centered instruction and higher self-efficacy scores. Considering these findings are not statistically significant, I would need to have an alternate study design that specifically focuses on context.

I suggest that reform in science education would benefit from implementing research studies and interventions on a broader contextual scale because, although it is important to work toward improving individual educators' science teaching identities, they seem to be quite impacted by their context. For example, teachers' efficacies have been found to be "contagious" between school staff and can spread to create either an overall positive or negative school climate (Tschannen-Moran, Hoy, & Hoy, 1998). It has also been established that the opinions of teachers' administration and peers are major influencers on their practices (Milner, et al., 2012).

Therefore, we should be putting efforts into approaches that affect entire school climates in our attempts to improve individual science teaching identities.

Conclusion

For my study, I set out to provide teachers at Anara and Baya Elementary Schools with a reform-based professional development opportunity in science education. I aimed to positively influence their science teaching identities, including their self-efficacies, beliefs and practices. I developed and implemented a year-long Professional Learning Community with seventeen educators that focused on the Ambitious Science Teaching framework. A majority of participants indicated that this time and space was very beneficial to their science instruction as they are rarely offered professional development in this subject area. Overall, the teachers' self-efficacies, beliefs, and practices were positively impacted by the PHP-PLC intervention. The AST framework opened their eyes to the essential importance of student-centered science and deepened their concern about the district-adopted curriculum, FOSS, which they understood -- contrary to its intent and claim -- to be a constraint on their teaching. I believe many educators desire opportunities to improve upon their science teaching skills, but more importantly, they crave space and creative flexibility for their science curriculum. It is essential that we work towards providing more reform-based experiences for the sake of student learning. This is especially true for historically-excluded youth who rightfully deserve our education debt to them to be squarely and strongly addressed.

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APPENDIX A. IRB APPROVAL LETTER

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2420 Lincoln Way, Suite 202
Ames, Iowa 50014
515 294-4566

Date: 04/30/2018

To: [redacted]

From: Office for Responsible Research

Title: **Young Scientists and Ambitious Teachers Improving Health in an Urban Ecosystem**

IRB ID: **15-310**

Submission Type: Modification **Exemption Date:** 04/30/2018

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

1: Research conducted in an established or commonly accepted educational setting; involving normal educational practices, such as (i) Research on regular and special education instructional strategies, or (ii) Research on the effectiveness or the comparison among instructional techniques, curricula, or classroom management methods.

The determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as described in the IRB application.** Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any *modifications to the research procedures* (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the *inclusion of participants from vulnerable populations*, and/or any *change that may increase the risk or discomfort to participants*. The purpose of review is to determine if the project still meets the federal criteria for exemption.

  In addition, ***changes to key personnel*** must receive prior approval.

  Detailed information about requirements for submission of modifications can be found on our website. For modifications that require prior approval, an amendment to the most recent IRB application must be submitted in IRBManager. A determination of exemption or approval from the IRB must be granted before implementing the proposed changes.

Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

Please note that you must submit all research involving human participants for review. **Only the IRB or its designees may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.

Please be aware that **approval from other entities may also be needed**. For example, access to data from private records (e.g., student, medical, or employment records, etc.) that are protected by FERPA, HIPAA or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted**.

Please be advised that your research study may be subject to **post-approval monitoring** **by Iowa State University's Office for Responsible Research**. In some cases, it may also be subject to formal audit or inspection by federal agencies and study sponsors.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX B. SIPS SURVEY INSTRUMENT AND SCORING GUIDE

The SIPS Survey was developed by Hayes, Lee, DiStefano, O'Connor, & Seitz (2016).

	Never	*Rarely (a few times a year)*	*Sometimes (once or twice a month)*	*Often (once or twice a week)*	*Daily or almos t daily*
How often do your students do each of the following in your science classes:					
1. Generate questions or predictions to explore	1	2	3	4	5
2. Identify questions from observations of phenomena	1	2	3	4	5
3. Choose variables to investigate (such as in a lab setting)	1	2	3	4	5
4. Design or implement their OWN investigations	1	2	3	4	5
5. Make and record observations	1	2	3	4	5
6. Gather quantitative or qualitative data	1	2	3	4	5
7. Organize data into charts or graphs	1	2	3	4	5
8. Analyze relationships using charts or graphs	1	2	3	4	5
9. Analyze results using basic calculations	1	2	3	4	5
10. Explain the reasoning behind an idea	1	2	3	4	5
11. Respectfully critique each others' reasoning	1	2	3	4	5
12. Supply evidence to support a claim or explanation	1	2	3	4	5
13. Consider alternative explanations	1	2	3	4	5
14. Make an argument that supports or refutes a claim	1	2	3	4	5
15. Create a physical model of a scientific phenomenon (like creating a representation of the solar system)	1	2	3	4	5
16. Develop a conceptual model based on data or observations (model is not provided by textbook or teacher)	1	2	3	4	5
17. Use models to predict outcomes	1	2	3	4	5
How often do you do each of the following in your science instruction:					
18. Provide direct instruction to explain science concepts	1	2	3	4	5

19. Demonstrate an experiment and have students watch	1	2	3	4	5
20. Use activity sheets to reinforce skills or content	1	2	3	4	5
21. Go over science vocabulary	1	2	3	4	5
22. Apply science concepts to explain natural events or real-world situations.	1	2	3	4	5
23. Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water).	1	2	3	4	5
24. Discuss students' prior knowledge or experience related to the science topic or concept.	1	2	3	4	5
Science Discourse and Communication ***(for consideration- items 25 to 31 were not included in the final survey)***					
How often do your students do each of the following in your science classes:					
25. Write about what was observed and why it happened	1	2	3	4	5
26. Present procedures, data and conclusions to the class (either informally or in formal presentations)	1	2	3	4	5
27. Read from a science textbook or other hand-outs in class	1	2	3	4	5
28. Critically synthesize information from different sources (i.e. text or media)	1	2	3	4	5
How often do you do each of the following in your science instruction:					
29. Use open-ended questions to stimulate whole class discussion (most students participate)	1	2	3	4	5
30. Have students work with each other in small groups	1	2	3	4	5
31. Encourage students to explain concepts to one another	1	2	3	4	5

SIPS Scoring Guide

The following scoring instructions were provided by the creators of the SIPS survey: "To score the SIPs survey, a unique score should be calculated by averaging the ratings of items within that factor. For example, for the factor "Instigating an Investigation", the score will be the average ratings from items 1 to 4" (Hayes et al., 2016).

Factor	NGSS SE Practice	Survey Item	Score
1. Instigating an Investigation	1 (Questioning) 3 (Planning and Carrying Out an Investigation)	1. Generate questions or predictions to explore	Average of items 1 to 4: _______
		2. Identify questions from observations of phenomena	
		3. Choose variables to investigate (such as in a lab setting)	
		4. Design or implement their OWN investigations	
2. Data Collection and Analyses	3 (Planning and Carrying Out an Investigation) 4 (Analyzing and Interpreting Data) 5 (Using Mathematical and Computational Thinking)	5. Make and record observations	Average of items 5 to 9: _______
		6. Gather quantitative or qualitative data	
		7. Organize data into charts or graphs	
		8. Analyze relationships using charts or graphs	
		9. Analyze results using basic calculations	
3. Critique, Argumentation, and Explanation	6 (Constructing Explanations) 7 (Engaging in Argument from Evidence)	10. Explain the reasoning behind an idea	Average of items 10 to 15: _______
		11. Respectfully critique each others' reasoning	
		12. Supply evidence to support a claim or explanation	
		13. Consider alternative explanations	
		14. Make an argument that supports or refutes a claim	
4. Modeling	2 (Developing and Using Models)	15. Create a physical model of a scientific phenomenon (like creating a representation of the solar system)	Average of items 16 to 18: _______
		16. Develop a conceptual model based on data or observations (model is not provided by textbook or teacher)	
		17. Use models to predict outcomes	

5. Traditional Instruction		18. Provide direct instruction to explain science concepts 19. Demonstrate an experiment and have students watch 20. Use activity sheets to reinforce skills or content 21. Go over science vocabulary	Average of items 19 to 22: ______
6. Prior Knowledge		22. Apply science concepts to explain natural events or real-world situations. 23. Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water). 24. Discuss students' prior knowledge or experience related to the science topic or concept.	Average of items 22 to 24: ______
Science Discourse and Communication ***(For consideration- items 25 to 31 were not included in the final survey)***	8 (Obtaining, Communicating, and Evaluating Information)	25. Write about what was observed and why it happened 26. Present procedures, data and conclusions to the class (either informally or in formal presentations) *27.* Read from a science textbook or other hand-outs in class 28. Critically synthesize information from different sources (i.e. text or media) 29. Use open-ended questions to stimulate whole class discussion (most students participate) 30. Have students work with each other in small groups 31. Encourage students to explain concepts to one another	Average of items 25 to 31: ______

APPENDIX C. STEBI-A SURVEY

In order to measure the influence of the professional learning community on the participants' self-efficacy in science teaching, I utilized the survey tool, Science Teaching Efficacy Belief Instrument (STEBI), developed by Iris Riggs and Larry Enochs (1990).

Science Teaching Efficacy Belief Instrument*

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA = Strongly Agree
A = Agree
UN = Uncertain
D = Disagree
SD = Strongly Disagree

1.	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	SA A UN D SD
2.	I am continually finding better ways to teach science.	SA A UN D SD
3.	Even when I try very hard, I don't teach science as well as I do most subjects.	SA A UN D SD
4.	When the science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.	SA A UN D SD
5.	I know the steps necessary to teach science concepts effectively.	SA A UN D SD
6.	I am not very effective in monitoring science experiments.	SA A UN D SD
7.	If students are underachieving in science, it is most likely due to ineffective science teaching.	SA A UN D SD
8.	I generally teach science ineffectively.	SA A UN D SD
9.	The inadequacy of a student's science background can be overcome by good teaching.	SA A UN D SD
10.	The low science achievement of some students cannot generally be blamed on their teachers.	SA A UN D SD
11.	When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.	SA A UN D SD
12.	I understand science concepts well enough to be effective in teaching elementary science.	SA A UN D SD
13.	Increased effort in science teaching produces little change in some students' science achievement.	SA A UN D SD
14.	The teacher is generally responsible for the achievement of students in science.	SA A UN D SD
15.	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	SA A UN D SD
16.	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	SA A UN D SD
17.	I find it difficult to explain to students why science experiments work.	SA A UN D SD
18.	I am typically able to answer students' science questions.	SA A UN D SD
19.	I wonder if I have the necessary skills to teach science.	SA A UN D SD

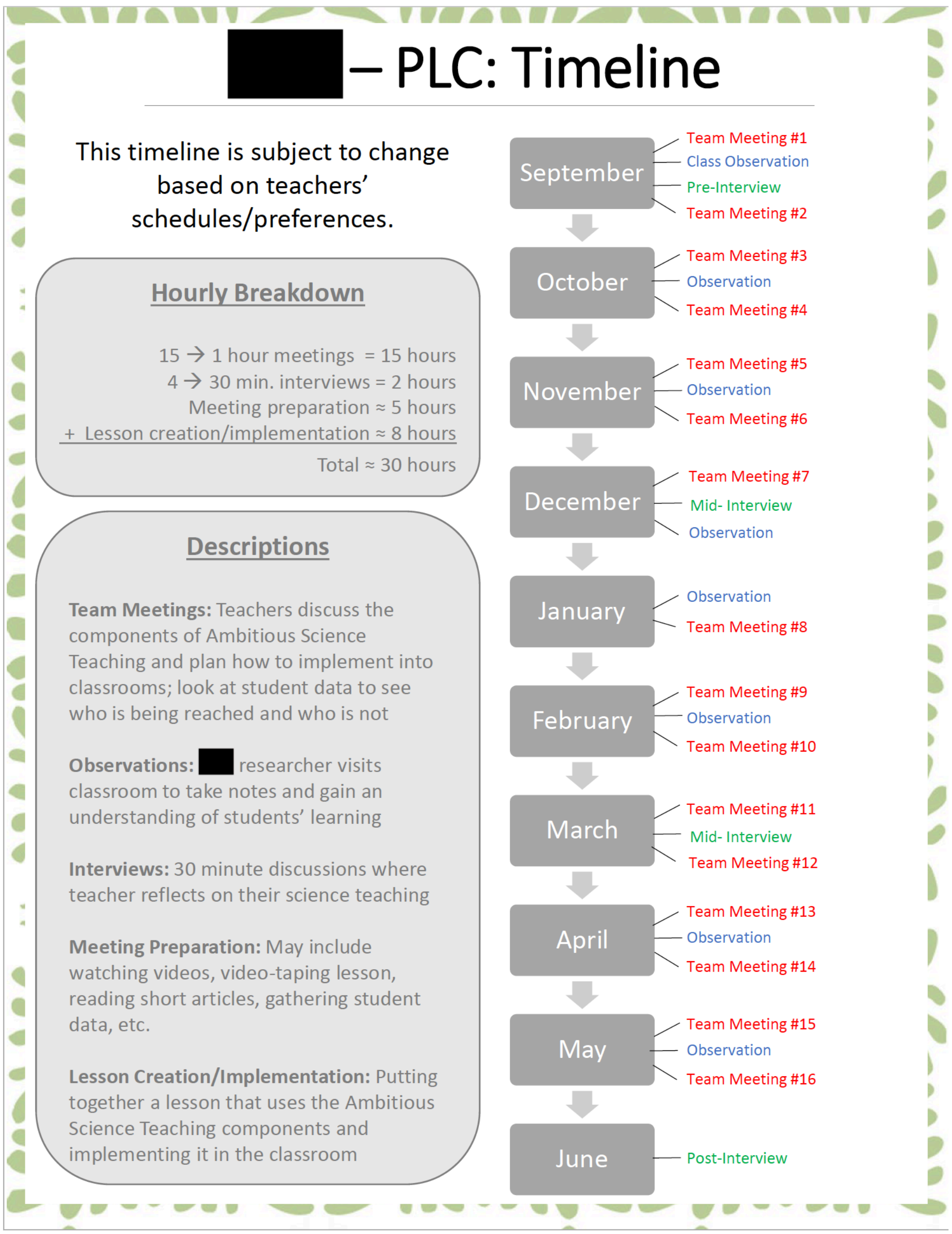
20.	Effectiveness in science teaching has little influence on the achievement of students with low motivation.	SA A UN D SD
21.	Given a choice, I would not invite the principal to evaluate my science teaching.	SA A UN D SD
22.	When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	SA A UN D SD
23.	When teaching science, I usually welcome student questions.	SA A UN D SD
24.	I don't know what to do to turn students on to science.	SA A UN D SD
25.	Even teachers with good science teaching abilities cannot help some kids learn science.	SA A UN D SD

*In Riggs, I., & Knochs, L. (1990). Towards the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*, 625-637.

APPENDIX D. PHP-PLC INITIAL TIMELINE

Timeline Provided to Participants

I developed this PHP-PLC timeline with quite the overly ambitious intentions of conducting many observations and interviews. I did not observe the teachers throughout the school year, and I replaced the mid-interviews with the Mid-Survey and Pre-Unit Survey.



APPENDIX E. PRE-INTERVIEW PROTOCOL

Interviewer:

Teacher:

Grade:

School:

Date:

PHP-PLC Pre-Interview Questions

1. What is your background with teaching science (i.e. years of experience, education background, professional development participation, etc.)?
2. How do you feel about teaching science (before becoming involved in this project)? What do you like about it, or not like about it?
3. How often and when do you teach science?
4. How do you feel about planning/prepping for science?
5. What pedagogical methods do you use when teaching science? Why?
6. What does a typical science lesson structure look like for you?
7. What do you think is important for your students when teaching science? What goals do you have for your students during science lessons?
8. How do you assess students in science?
9. If anything, what would you like to change about and/or add to your science teaching practices?
10. Anything else you would like for me to know?

NOTES:

APPENDIX F. POST-INTERVIEW PROTOCOL

Interviewer:

Teacher:

Grade:

School:

Date:

Time:

Interview Type: Semi-structured Interview

PHP-PLC Post-Interview Questions

Introduction:

Overview and Purpose:

I want to begin by thanking you for all time and effort you put into the UEP – PLC. As a member of the Urban Ecosystem Project – a program that utilizes AST practices in its curriculum – I am interested to learn your perspective on the AST framework. There are no right or wrong answers to my questions or prompts. Want to give you some time to look at the questions and discuss

- Look at year timeline for social studies/science units
- Give time to look at surveys
- Look at reflection/video clip reflection
- Ask questions

Informed Consent:

Is it okay if I record this interview?

Body of the Interview:

Theme: Science Teaching Beliefs, Identities, and Practices (Post-PLC)

Elaborations/Questions:

- Please describe your science unit plan timeline throughout the school year.
- Tell me about your experience with the UEP – PLC.
- How have your answers from these questions in our initial interview changed after participating in the UEP – PLC?
    - How do you feel about teaching science (after becoming involved in this project?) What do you like about it, or not like about it?
    - How do you feel about planning/prepping for science?

- o What pedagogical (teaching) methods do you use when teaching science? Why?
- o What does a typical science lesson structure look like for you?
- o How has the PLC and AST impacted your science lessons?
- o What do you think is important for your students when teaching science? What goals do you have for your students during science lessons?
- o How do you assess students in science?
- o If anything, what would you like to change about and/or add to your science teaching practices?

- What Ambitious Science Teaching practices did you find helpful/practical? What practices did you find challenging? (Look at all AST practices)
- What are your future goals for science teaching?
- What else would you like to share about your experience with the UEP – PLC or the AST framework?

Transitions:

TABLE 7.1 Follow-Up Questions

Open-Ended Elaborations	Purpose
Would you tell me more about that?	More detail
That's helpful. I'd appreciate it if you'd give me more detail.	More detail
I'm intrigued by what you're telling me, but I'm not sure I get the whole picture yet.	More detail
Open-Ended Clarifications	**Purpose**
I want to be sure I understand. Could you go over that again?	Rephrasing
I think I see what you mean, but I'm not sure I understand fully.	Implying that more detail will help
Detailed Elaborations	**Purpose**
Who else was there?	Others present
When did all this happen?	Timing of events
Describe the room.	Physical environment
How were you involved? What was your role?	Interactions and roles
Where did this happen?	Location

*Note: This table is from the fourth edition textbook, An Introduction to Qualitative Research: Learning in the Field, by Gretchen Rossman and Sharon Rallis (Rossman & Rallis, 2017).

Closure:

Your perspective is valuable to understanding the relationship of AST in education settings – formal and informal. Sharing experiences like yours helps progress the way we understand science teaching. Thank you again for your time and for sharing your perspective with me!

Interview Notes:

-

APPENDIX G. INTERVEW DATA ORGANIZATION EXAMPLE

Here is an example screenshot of how I organized and highlighted the interview data to find themes. The columns are organized by interview question and the rows are the responses for each participant. In the final column, I added my interview notes. In the final row, I inputted overarching themes.

Pre-Interview		
What pedagogical methods do you use when teaching science? Why?	What does a typical science lesson structure look like for you?	What do you think is important for your students when teaching science? What goals do you have for your students during science lessons?
Pedagogical Methods: I think lots of questioning, and trying to teach them the scientific method and you use it, because I have found that when the students are generating the questions, then they're more engaged, and it's more meaningful than if I'm creating a bunch of questions for them to try and figure out. Sometimes in the beginning, I think you have to do that to be able to be like, "Hey, what do you think is going to happen," but yeah, trying to do questions, and getting them to create maybe some higher level questions, which is a little hard. They like to do less of the identifying or knowing questions instead of the analyzed types of questions.	**Lesson Structure**: Maybe like an introduction of the topic, and then hopefully some kind of activity or experiment where they're trying to figure something out, or seeing what happens and working with a group or a partner to try and figure that out. One because materials, and two, because then you don't have like one person who's like, "Mine doesn't work." It usually works better if there are two or three of them working together, and then it would be like intro, or not really mini lesson, but discussion, activity, and then gathering for a culminating discussion and reflection on what happened, and then if we have to do readings, it would probably be after that to try and cement it.	**Goals**: I guess understanding the concepts. I just want them to have a good firm grasp and understanding of what's happening and why. I wanted them to be engaged and enjoy it. I think they do enjoy science when it's hands-on. If it's all just reading texts, science, nonfiction texts that's not fun and engaging. That's just more reading, and I think our goal, because we don't have a lot of time, is to try and maybe include some of those texts, and that nonfiction texts in our literacy or reading time. Maybe it drives more of our small group reading. If we can read articles and things that back up our science concepts, that'll give us a little extra push or amount of time, getting that material across.
Pedagogical Methods: Because I believe that children learn and people learn through discovering it on their own rather than someone telling them. I can't remember what it's called, but it was developed by the Science Museum of Minnesota, where you give them a question and then they have to try to solve it. It's like make this windmill and here's a bunch of materials. They try to solve it and then they come back and they revamp it ... the engineering design process, that's what it was called. And hopefully get through all the steps. There's a lot of steps, but I try, I attempt.	**Lesson Structure**: A quick intro. Either a discrepant event or a picture, or a quick write about something. Yesterday we did drawing on your whiteboard, 'what is a scientist, who is a scientist.' Then we talked about that like three minutes. And then we do this really cool thing that my EL teacher is spearheading and we choose a vocabulary word. On the first day you just say the word and the students make predictions about what it means and you teach them the sign language for it. Throughout the week they get more information about the word, but you don't actually give them the definition until Friday. Then we do our word of the day and then we go into the actual lesson. Whether that's exploring something or going back to something we did the next day or, or the previous day. Today we're doing two stations and we're exploring with shadows and flashlights. End it with some kind of reflection. Sometimes it's just a partner pair-share sometimes it's a whole group share, sometimes it's writing. But some kind of reflection.	**Goals:** My goal is for them to be asking questions and trying to figure out how to answer the question on their own. So, looking for, thinking critically and ... it's definitely more about the thinking process rather than what concrete answer are you finding? Obviously we have to get some concrete answers in there, but a lot more about the process because I think that's applicable in their daily life. And I think that will encourage them to continue going into science and studying more in science. If they can think critically and work on problem solving and enjoying science, then they're going to get farther in it. Then they'll get all the concrete reasoning later in life.
Pedagogical Methods: Questioning. Letting them, as much as you can, kind of guide your investigation. We will often watch videos if it's something like waves. Listening to or watching videos about different waves. We try to integrate reading with our science, so often, if we're working on an informational standard in reading, we'll try to have it be about waves so that they're learning in that way too and answering questions about it. Definitely hands on most of the time, if it can be. And there's a lot of group work, so I put students into groups, and they each have a job, and they kind of feel like they're in charge of that job, and we'll switch groups every once in a while, and we'll switch jobs every investigation. And some of the kids take their jobs very seriously. It gives them kind of a purpose.	**Lesson Structure:** Sometimes on day one, it's a lot of we're digging into background knowledge. "What do you know about the topic? What can you share? What are some things that you're curious about?" And also day one, were doing vocabulary types of things. So when we plan an investigation, we look at vocabulary that's going to come up, and also on the scale there's vocabulary. And so we'll use that, and a lot of times we'll spend the first day seeing what they're curious about, but then also touching vocabulary too. And then hopefully by the mid-to-end of the week, we're beginning the investigation. A lot of times it's not just a one-day thing, it's like a two or three-day. And then by Friday, we try to wrap up with their final project or their final test or whatever it is, and then also have some sort of assessment that we can use as a grade for science. **Example**: And yesterday, we were making these waves out of different materials, and I had the materials all over the table, and I had a sign that said please do not touch. And the kids were	**Goal:** Collaboration is huge. And I feel like that's something we're always working on. But for them to be participating and trying, and not sitting back and letting others do the work. I want for them to be curious about science, and not just do whatever you're doing because the teacher says so. Just for them to be curious. I like for them to learn something in class, and then read about it in reading, or they'll find a book and be really excited about it. I think also their enthusiasm about science is... I love it when they're excited and asking questions. **Example:** For instance, today I had a group who was making their wave out of yarn, and I gave them a piece of tape to tape it down. It was like that thick tape that you use for boxes. And as one of the kids was going to put the tape down, the yarn kind of lifted up off of the construction paper, and one of the kids was like, "Look, there's a magnet in the yarn." And I said, "Is that possible? Is there a magnet in the yarn?" You know? And then I was like, "What do you have to have to create a magnet?" And he was like, "Some sort of iron." And I said, "So is there iron in the yarn? Do you really think with this flexible yarn, there's iron in there?" And he's like, "I don't know. Probably not." And I said, "So what do you think it is?" And one of the kids was just kind of playing with it, and the other kid, I'm like, "Well, what is it? Because if there's not a magnet, what is doing this?" And he's like, "There must be some sort of electricity in there." I'm like, "Maybe." And I'm like, "What kind of electricity could be in there if there's no wires, or nothing that's carrying electricity?" And he's like, "I don't know, but maybe the kind like when you rub your socks on the carpet." And

APPENDIX H. CASE STUDY PROFILE EXAMPLE

Here is an example screenshot of how I organized and highlighted the Tier 2 participants' data to conduct the contrastive case studies. I highlighted the responses based on whether they related to the teacher's self-efficacy, beliefs, or practices. The documents were around twenty-pages long.

Brandi - Case Study Profile

<table>
<tr><th colspan="3">BACKGROUND</th></tr>
<tr><td>Grade: 4th</td><td>Years Teaching: 3rd year</td><td>School: Baya Elementary School (School B)</td></tr>
<tr><td colspan="2">Education Background:
• Bachelors in El Ed
• Took six masters classes for teaching STEM</td><td>Teaching Background:
• Been teaching at School B for 2 years</td></tr>
<tr><td colspan="3">Other:
• Masters classes: “They taught us the different ways of teaching, of like open-ended questions and making the kids explore, not having like a certain scientific method or a certain way of doing science. So I changed that around a lot and did a lot of like pre and post-tests of their understanding, and it just got them really more excited about science and let them more be free and able to ask questions and want to make their own experiments kind of thing. I just took it kind of as a class, because I'm going through the Blue contract so I get my Masters paid for starting in January, so I just did it as like some free courses just to learn for fun.”</td></tr>
</table>

<table>
<tr><th colspan="4">SCIENCE TEACHING IDENTITY
Self-Efficacy Beliefs Practices</th></tr>
<tr><td>Identity Component:</td><td>Pre PLC
Pre-Interview (PI) & Surveys (P-SIPS, P-STEBI), Observations (PO), Meeting Notes (PN)</td><td>Mid PLC
Mid-survey (MS), Pre-Unit Survey (MUS), Meeting Notes (MN)</td><td>After PLC
Post-Interview (AI) & Surveys (A-SIPS, A-STEBI), Reflections (AR), Observations (AO), Meeting Notes (AN)</td></tr>
<tr><td>How do you feel about teaching science? What do you like about it, or not like about it?</td><td>• (PI) Likes: I actually very much love teaching science, but the only thing that scares me is a lot of the times I don't know a lot about the science either, so it's like a learning process.
• (PI) Dislikes: The only thing that discourages me about science is just the amount of - the way that we teach it now - the amount of prep that the curriculum we have you need to do.
• (PI) General Beliefs: And when kids ask me questions that I don't know, I just have to tell them, "Let's find out</td><td>•</td><td>• Even at the beginning of the year I totally remember me being, "I have no idea how to teach science, I don't know how to answer the questions." Even though now I feel like I've learned a little bit more on this scales and information about science it's not like I've grown more deeper and understand the science knowledge. It's more of how to handle teaching science and how to explore with the kids because even though I still might not know the answers, it's not like I just say, oh, I don't know and then we don't ever think about it. It's like,</td></tr>
</table>

APPENDIX I. PHP-PLC MEETING PLAN AND NOTES EXAMPLE

Here is an example of a plan with reflection notes that I would complete for each PHP-PLC meeting. This particular plan was for the "Seasoned Squad" at Baya Elementary School.

<table>
<tr><td>Grade: 4th</td><td>School: [redacted]</td><td>Date: 2/07/18</td><td>Time: 2:45 - 3:45 p.m.</td></tr>
<tr><td colspan="4">Participants: [redacted]</td></tr>
<tr><td colspan="2">Meeting Prep:
● Email teachers two days in advance
● Print off materials for binders (3 hole punch)</td><td colspan="2">Materials:
● Binders
● AST book
● Trifold
● Notecards
● Sticky notes</td></tr>
<tr><td colspan="2">Meeting Plan:</td><td colspan="2">Meeting Notes:</td></tr>
<tr><td colspan="2">2:45 - 2:50 [Plan the semester]
● Checking in
● Ask about a possible workshop day, and when the teachers think it would work for a majority of them
○ Friday, March 15th - Conference Days
○ Mon/Tues. March 25th/26th - Staff Devel.
○ During Spring Break?
○ How long? Is 4 hours too much?

2:50 - 3:05 [Discuss Phase 4]
● Refer to the AST brief overview sheet
● Look in the AST book
○ P. 217 - "Gotta have checklist"
■ Provide "Gotta have checklist" handout
○ P. 220-1 - Decisions to make beforehand
○ P. 227 - Example of initial and revised hypotheses list
○ P. 230 - Student criteria for assessing a hypotheses list
● Look at the Phase 4 Teaching Practice Tool
○ Provide handout and go over some of the example questions

3:05 - 3:30 [Big ideas; anchoring phenomena; essential question]
● Unit document: https://docs.google.com/document/[redacted]
● P. 23 - "Big ideas" whiteboard activity
● Look at standards and pick out big ideas students must learn</td><td colspan="2">● Ambassador: have one student per group to go to other groups and see what they think (about the models, explanations, questions, etc.) and then go back to original group to report what others thought
● Teachers requested to have video examples of AST sent to them
● 4 themes (one per week) for teachers to rotate through
○ Mosquitoes
○ Bees
○ Daffodils
○ ?
● There are 20 days for the unit (4 weeks and 2 days)
● Unit: 03/27-04/26</td></tr>
</table>

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<tr>
<td>

- Choose an anchoring event - remember it should be specific
- Write an essential question to go along with the anchoring event

3:30 - 3:45 [Brainstorm activities]
- When will Unit 8 begin? How many lessons?
- What lessons will help students better understand the anchoring phenomena and essential question?

</td>
<td></td>
</tr>
<tr>
<td colspan="2">

Reflection:
- One teacher mentioned how student really like to check each other's work, which could be useful for formative assessments
- FLIP GRID - The teachers like to use Flip Grid for assessments because it allows for students to video tape what they are thinking
- A common request from teachers is to have video examples of AST lessons ([redacted] was requesting)
- We decided to have four themes throughout the unit (one each week) and teachers will rotate and teach different themes each week. This way, each teacher can have assistance for the mosquito week.
- Some teachers are moving to different classrooms and grades next year. Two teachers are staying ([redacted] and [redacted]), while [redacted] is moving to 5th grade and [redacted] is moving to 3rd grade. [redacted] is going from ELL to a 2nd grade classroom.
- There seems to be some disagreements with administration decisions
- [redacted] seemed really excited about her ideas and pressed for them multiple times to be used; she has a large packet full of materials and activities

</td>
</tr>
</table>

APPENDIX J. AST PHASE 3 – ADJUSTED LESSON PLAN TEMPLATE

To support the participants during their science unit planning, I slightly adjusted the AST practice suggestions to relate it to the 5E model, which some teachers were already familiar with. This template was for the third phase of AST: supporting ongoing changes in thinking (Windschitl, Thompson, & Braaten, 2018).

Procedure:

1. **Engage: Activate prior knowledge and experiences (whole class)**
    a. Remind students of prior lessons and ideas by referring to anchor charts and models
        i. Refer back to the essential question:
        ii. "Today..."
    b. Provide information to leverage during the activity
        i. Link verbally what was done by student previously to a "need to know" new idea
            1. Discuss the two activities in the lesson:
        ii. Be explicit about new vocabulary being introduced
        iii. Use multiple representations of the idea, ask students to look across these and compare how the idea shows up
2. **Explore: Get the hands-on activity started: helping students uncover observation and patterns (small groups)**
    a. A hands-on activity that will support students' ongoing changes in thinking
        i. Activity:
        ii. Provide instructions:
        iii. Have students get into their small groups and assign students "jobs" for when they are working in small groups during the activity (i.e. materials gatherer, timer, recorder, reporter, etc.)
    b. Make observations and uncover patterns using questions as students are working
        i. Teacher walks around to each group and asks students about their observations, patterns they see, inferences and connections they have
    c. Helping students connect the activity to the anchoring phenomenon as they are working
        i. Teacher walks around a second time to each group and asks questions to see if students understand WHY they are doing this activity
            1. "Can you explain what you are doing or what is happening in terms of [the anchoring phenomena]?"
3. **Explain: Whole class coordination of students' ideas and their questions (whole class)**
    a. Publicly share observations
        i. "What did you find?"
        ii. "I heard these three hypotheses, which ones do you agree with? Based on what evidence?"
4. **Elaborate: Have students use their newly learned knowledge in a new context (small group)**
    a. Activity:
    b. Provide instructions:
    c. Ideas: change the activity slightly, add another level to the activity, read an article and make connections to the activity, data analysis, experiment related to the activity, etc.
    d. Walk around and scaffold students
5. **Evaluate: Create or revise a public record of student thinking (whole class)**
    a. Discuss how this lesson/activity added/changed their knowledge related to the anchoring phenomena
        i. Option 1: Add to, revise, consolidate an explanation checklist
        ii. Option 2: Use post-it notes to revise your small group models

APPENDIX K. INITIAL PHP-PLC PLAN

The PHP-PLC provided teachers the option of earning license-renewal credits for participating in the professional development intervention. The following plan was given to the local Heartland AEA to communicate enrollment expectations for those who chose to take the credits.

Ambitious Science Teaching and Learning

Activity Objectives

Not Applicable

Activity Requirements

(NOTE: If credit is being offered for this activity, the requirements are the same whether the participant is taking the class for license renewal credit or graduate credit. A passing grade for license renewal credit is the equivalent of an 'A' or 'B' letter grade in a graduate course.)

100% attendance - minimum of 30 contact hours
Active class participation
Completion of science unit using Ambitious Science Teaching practices

Participant Evaluation:
P/Pass Grade - Completion of science project cycle

F/Fail - The participant did not meet the above requirements.

NOTE: All participants, including those registering as "Participant Only," should plan to complete all of the work required (attendance, participation and assignments) to receive the full benefit of the training.

Learning Design

Item / Event / Task / Activity	In Class Hours	Out of Class Hours
Task: Participate in fifteen one-hour meetings to study and discuss the components of Ambitious Science Teaching by using the book indicated above and online tools/articles. During the meetings, we will determine and plan how to implement specific Ambitious Science Teaching practices into the science curriculum for a specified unit related to the NGSS and [redacted] standards. The meetings will focus on the following topics (in order): 1. Current science teaching practices/goals 2. An overview of Ambitious Science Teaching and how it compares/contrasts to current science teaching practices (Chapter 1) 3. Study and discuss Phase #1 of Ambitious Science Teaching: planning for engagement with big science ideas (Chapter 2) 4. Planning the chosen science unit using phase #1 practices 5. Study and discuss using talk as a tool for learning (Chapter 3 & 4) 6. Study and discuss Phase #2 of Ambitious Science Teaching: eliciting students' ideas (Chapter 5) 7. Planning the chosen science unit using phase #2 practices 8. Study and discuss using models as assessments (Chapter 6 & 7) 9. Study and discuss Phase #3 of Ambitious Science Teaching: supporting ongoing changes in thinking (Chapter 8, 9, & 10) 10. Planning the chosen science unit using phase #3 practices (note: this will take more time because it involves planning the majority of the lessons in the unit) 11. Planning the chosen science unit using phase #3 practices 12. Planning the chosen science unit using phase #3 practices 13. Study and discuss Phase #4 of Ambitious Science Teaching: pressing for evidence-based explanations (Chapter 11 & 12) 14. Planning the chosen science unit using phase #4 practices 15. Finalizing the unit	15	0
Event: Participate in a one-day, five hour workshop to collaborate and plan with teachers from both schools to provide and receive ideas for future science teaching purposes.	5	0
Task: Implement the planned science unit using Ambitious Science Teaching practices in the classroom (-spread over four weeks)	8	0
Interviews: Participate in four 30 minute interviews to debrief and reflect upon science teaching and the effects of Ambitious Science Teaching practices	2	0
Total Hours	**30**	**0**